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PHILIPPINE RICE-MILL PRODUCTS WITH PARTICULAR REFERENCE TO THE NUTRITIVE VALUE AND PRESERVATION OF RICE BRAN

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TEN PLATES AND ONE TEXT FIGURE

Rice serves as the principal food for people of the Far Eastern countries. In the Philippines the diet of the masses consists largely of rice and is more or less deficient in fats, proteins, and vitamins. This investigation of Philippine rice-mill products, particularly rice bran, was undertaken with the idea of endeavoring to supply the present dietary deficiency.

In the Philippine process of milling rice the hull is first removed leaving the kernel which is somewhat colored and commonly called unpolished rice. The unpolished rice does not keep well because, when stored, the fats in it become rancid. Again the unpolished rice becomes infested with insects which destroy the outer mealy layer of the grain. To produce white polished rice, which can be handled without commercial hazard, the rice kernel is passed through a combined scraping and polishing process. This removes the outer portion of the kernel together with the embryo. That portion of the kernel removed during the polishing process is called rice bran. The bran is also known locally as darak, tikitiki, or rice polishings.

Rice bran is the most nutritious part of the rice since it contains fats, proteins, and vitamins. The fats in rice bran are about the same as those in peanuts which are considered quite nutritious. The proteins are very similar to meat proteins since

they contain in their make-up about the same important amino acids. Rice bran contains vitamin B_1, which prevents beriberi, and vitamin A, which prevents eye afflictions and general ill-health. It also has the antisterility vitamin E.

At present rice bran is very cheap and is used for feeding cattle and poultry. Millers sometimes dilute the bran with rice hulls in order to dispose of the hulls with profit. Bran, which has been adulterated with rice hulls, is not suitable for use as an edible product because the hulls have an irritating effect when taken internally.

Bran flours are considered quite nutritious and are very popular in the United States and other countries. This would naturally suggest the use of rice bran for human consumption, especially since the bran is very much cheaper than flour. Several American teachers informed us recently that some years ago in the Philippine provinces they tried to make a bran flour by mixing rice bran with wheat flour. Although this mixture made very good bread and cakes they discontinued using it because they found it difficult to obtain a regular supply of high-grade bran. Sometimes the bran was fresh and at other times it was not.

The reason that rice bran has not become a popular human food is probably due to the fact that it contains a quantity of vegetable fatty oil (rice oil). When the rice bran is stored the oil becomes rancid and the bran acquires a disagreeable taste. Millers often pile fresh bran on top of stale bran. To be sure of getting fresh bran one should really go to the mill and take the bran as it comes fresh from the polisher.

The decomposition of the fatty oil in rice bran is due to the action of moisture in the presence of vegetable tissue which contains fat-splitting enzymes. We found that rancidity may be prevented by heating the fresh bran at a temperature of about 105° C., for three hours and storing it in moisture-proof containers which preserve the bran and prevent access of insects. Heating the bran removes moisture and stops the destructive action of enzymes. This prevents decomposition and subsequent rancidity of the fatty oil contained in the bran. The heating also destroys any mold spores, insects, or insect eggs which may be in the bran but does not affect the vitamins.

Bran treated in this manner is slightly darker in color than the fresh, raw bran but it has a pleasanter and sweeter odor and flavor than the raw bran. It does not become moldy or

rancid; in fact, it may be kept in a fresh condition for a considerable length of time without any appreciable deterioration.

In preparing rice bran for storage it is advisable to use a specially constructed cooker containing a stirrer. Stirring the bran while heating facilitates the removal of moisture. In outlying districts where proper cooking facilities are not available the bran may be heated cautiously in a frying pan over a low fire. The bran should be stirred and the heating continued for perhaps an hour until it turns slightly darker in color. After heating, the bran should then be placed in a can or glass jar which may be closed tightly to prevent access of moisture. Bran, thus prepared, keeps for about a week or more.

Miss Maria Y. Orosa, of the Bureau of Science, has prepared excellent cakes, cookies, and bread from mixtures of wheat flour and rice bran. She used fresh bran and also bran which had been heated and stored for two months. The results were the same in each case. These bakery products were very satisfactory in texture and quite tasty.

For people who do not fancy the natural flavor of rice bran this may be toned down considerably by diluting the bran with wheat flour. A mixture of wheat flour (3 parts) and rice bran (1 part) makes a good combination for bakery products such as bread and cakes. When used alone rice bran, lacking gluten, does not make bread which will rise. The addition of wheat flour serves not only to dilute the bran but also to supply the gluten necessary for making bread.

The bran flavor may be still further neutralized or entirely disguised by using other characteristic flavors, such as ginger, cinnamon, or chocolate. Bran cookies made with these flavors are very tasty and since they contain vitamins they are quite nutritious.

In the Philippines beriberi is a very common and fatal disease among the poorer classes who live on a diet that consists principally of polished rice and is deficient in vitamin B_1. For a number of years the Bureau of Science has been making a standard extract of rice bran (tikitiki extract) which contains vitamin B_1. This extract is widely used for curing or preventing beriberi. It has been estimated that for adults approximately 30 grams of high-grade rice bran contain about enough of the antineuritic vitamin B_1 for their daily requirements as a preventative of beriberi. This is about equivalent to 11 level (not heaping) teaspoonfuls of bran or approximately 2 cubic centi-

meters of standard rice-bran extract. More than 111,000 tons of fine rice bran are produced annually, in the Philippines, as a rice-mill by-product. As a preventative of beriberi this amount is about sufficient for all the people who need the bran for its medicinal value and also for others who might benefit by using it.

In a very few localities in the Philippines the people have for years been used to eating a kind of cake made from a mixture containing some fresh rice bran. If this use of rice bran as a human food could be popularized and the people all over the Islands become accustomed to eating bakery products or other foods containing rice bran then deaths from beriberi would be a rarity. It would not be necessary for the poorer classes to take extract of rice bran as a preventative or cure for beriberi.

Rice bran produced at present in the Philippines is not taken care of properly and much of it is allowed to spoil and is wasted. By utilizing this by-product of the rice mills as a food the health of the people would be generally improved. They would be getting not only vitamin B_1, which prevents beriberi, but also vitamins A and E and proteins similar to meat proteins. The children would be healthy and vigorous and would not appear to be improperly nourished. Moreover, by using a domestic by-product the Filipinos would be developing the natural resources of their own country and the importation of rice and other foodstuffs from foreign countries would be greatly diminished.

An outline of our investigation of Philippine rice-mill products and particularly rice bran is as follows:

OUTLINE OF INVESTIGATION

Rice cultivation.
Rice straw.
Philippine process of milling rice.
    Results in Philippine rice mills.
    Yields of Philippine rice-mill products.
Rice starch.
Rice hulls.
Polished and unpolished rice.
Nutritious parts of the rice grain.
    Embryo and aleurone layer.
Rice bran.
    Bran with rice hulls.
Rice oil (fats) in rice bran.
    Yield of rice oil.
    Composition of rice oil.
    Production of rice oil.

Vitamins in rice bran.
Vitamin B_1.
Rice-bran (tikitiki) extract.
Vitamin A.
Vitamin E.
Vitamin D in irradiated rice oil.
Chicken perosis.
Commercial importance of vitamins in rice oil.
Proteins in rice bran.
Rice bran lacks gluten.
Unbalanced mineral constituents.
Nutritive value of rice bran.
Rice bran as a cattle food.
Rice bran as a human food.
Rice bran as a preventative of beriberi.
Deterioration of rice bran.
Insect infestation.
Decomposition of rice oil.
Preservation of rice bran.
Preliminary heating experiments.
Wrappers for heated bran.
Enzymes in rice bran.
Testing fat-splitting-enzyme activity.
Temperature and time of heating rice bran.
Bacteria in rice bran.
Sieving rice bran before heating.
Rice-bran cooker.
Heating bran in outlying districts.
Summary.

RICE CULTIVATION

There are many varieties of rice grown in the Philippines. According to habitat, method of cultivation, and general properties these numerous varieties are usually classified in terms such as upland and lowland rice, glutinous and nonglutinous. They are identified by certain trade names, such as Macan 1 (official No. 527), which are recorded as permanent numbers in the Philippine Bureau of Plant Industry. The different varieties are distinguished by their principal physical characteristics such as length, width, and thickness of the grain, the color of the hull and tips, flavor, and other properties. In general the late-maturing varieties give a larger yield per hectare than the early-maturing varieties.

Various methods are used for cultivating rice in the Philippines. One very common practice is to plant the rice in seed beds and later transplant the seedlings to the rice paddy (field). Chemical changes which occur during the ripening of rice grains

have been studied by Tadokoro and Abe.[1] In their report they refer to previous work along this line.

When the growing rice reaches maturity (Plate 1) it is cut and stacked in the field in well-ventilated shocks and allowed to remain there about a month in order to cure the grain (Plate 2, fig. 1). Changes, not well understood, take place during the curing process. If the grain is not cured thoroughly, before threshing, it heats during storage and the moisture content increases. As a result it is likely to spoil.

Good accounts of the cultivation of rice in the Philippines are given by Copeland,[2] Camus,[3] and Mendiola.[4] Literature references concerning the experimental work on rice in the Philippines have been compiled by Capinpin and Mendiola,[5] and also Alvarado.[6] Kondo and Isshiki [7] have recently published a rather comprehensive index of rice literature.

TABLE 1.—*Area planted and yields per hectare of paddy rice produced in the Philippines during the years 1921 to 1930.*[a]

Year.	Area planted.	Yield per hectare.	Yearly production.
	Hectares.	*Cavanes.*	*Cavanes.*
1921	1,673,380	25	
1922	1,661,430	26	
1923	1,675,870	26	
1924	1,737,910	24	
1925	1,725,500	26	
1926	1,755,920	27	
1927	1,807,060	27	
1928	1,786,960	27	
1929	1,775,460	28	
1930	1,812,800	28	
Average	1,741,229	[b] 26.4	[b] 45,968,445

[a] These data were compiled from the annual reports of the Philippine Bureau of Agriculture and Bureau of Plant Industry.

[b] 1 cavan (including sack) weighs 44 kilos; 1 metric ton = 1,000 kilos; 45,968,445 cavanes x 44/1,000 = 2,022,611 metric tons.

[1] Journal, Faculty of Agriculture, Hokkaido Imperial University, Sapporo, Japan 28 (1930) 350.

[2] Rice (1924) 220.

[3] Philip. Bur. Agr. Bull. 37 (1921).

[4] A Manual of Plant Breeding for the Tropics. College of Agriculture, University of the Philippines, Los Baños (1926) 41.

[5] A bibliographical index of the College of Agriculture contributions on agricultural crops, Philip. Agr. 15 (1927) 493.

[6] Philip. Bur. Agr., Philippine Agricultural Bibliography, part 1 (1916) 27.

[7] Ber. d. Ohara Inst. f. Landw. Forsch. 5 (1932) 325.

In Table 1 are given the area planted and yields per hectare of paddy (unhulled) rice produced in the Philippines during the years 1921 to 1930. For these ten years the average yearly production was 45,968,445 cavanes, which is equivalent to 2,022,611 metric tons.

RICE STRAW

Rice straw is obtained as a by-product in threshing rice. In the Philippines rice straw is used as packing material, bedding for cattle, fuel in finishing pottery, for making mats, brooms, sandals, and for various other purposes. Rice straw serves as a good bedding for the cultivation of edible mushrooms.[8]

Experiments on the use of Philippine rice straw as a raw material for the manufacture of paper were carried out by Reyes and Cruz.[9] They estimate that enough rice straw is produced in Bulacan Province alone to supply a 10-ton paper mill. Analysis of the rice straw from Bulacan Province is given in Table 2.

TABLE 2.—*Composition of Philippine rice straw.*[a]

Constituent.	Per cent.
Moisture	9.84
Ash	15.23
Fats and waxes	1.86
Cellulose	37.84
Aqueous extract	13.66
Pectose bodies	21.57
Total	100.00

[a] Reyes, F. D., and A. O. Cruz, Philip. Journ. Sci. 38 (1929) 374.

Philippine rice straw makes a very good tissue paper. Reyes and Cruz found that paper made from Philippine cogon grass is stronger than that made from rice straw. However, rice straw requires for digestion about one-third as much caustic soda as cogon and is easier to bleach. In the Philippines where chemicals are expensive this is a decided advantage. Again, since rice straw is a by-product in threshing rice no extra labor of cutting the straw is required as is necessary in the case of cogon grass.

PHILIPPINE PROCESS OF MILLING RICE

There is quite a difference in the appearance and arrangement of machinery in the numerous Philippine rice mills (Plate

[8] Vicencio, A., Philip. Agr. and For. 5 (1916) 119.
[9] Philip. Journ. Sci. 38 (1929) 367.

2, fig. 2, and Plate 3). Some mills are more or less home-made, while others have very modern equipment. All of these mills, however, carry on the same operations and produce polished rice with rice hulls and rice bran as the principal by-products.

The milling of rice (fig. 1) consists essentially in gradually breaking up the rice grain (paddy or unhulled rice) into products which are separated by a number of large shaking sieves. The local Tagalog names for Philippine rice-mill products are as follows:

	Local name.
Rice grain (paddy or unhulled rice).	Palay.
Rice hulls.	Ipa.
Unpolished rice (rice kernel).	Pinawa.
Rice bran.	Darak, tikitiki, polishings.
Finely broken grain.	Binlid.
White polished rice.	Bigas.

In the Philippine process of milling rice the grain (paddy rice) is first passed through a cleaning sieve that removes trash and straw. The paddy rice is then carried to the rice huller. This breaks the hulls which inclose the rice kernel (unpolished rice). Some paddy rice grains usually pass through the rice huller without the hulls getting broken. The mixture (hulls, unpolished rice, and paddy rice) emerging from the rice huller is then sieved to remove tips, very finely broken grain, and small pieces of hulls. The mixture is then carried forward to the blower which is the next unit in the process. This is a special compartment. It contains a fan which blows the hulls out into an exit tube where the hulls are usually carried to the boiler to be used as fuel. The unpolished rice containing some paddy rice then drops to the separator sieve. This separates the unpolished rice from the paddy rice which is carried back to the rice huller.

The unpolished rice is next taken to the polisher. Some mills have two polishers. In passing through the polisher the surface of the grain is scraped with an abrasive thus removing the seed coat together with some of the outer portion of the rice kernel. The germ of the rice grain, which is rich in oil, is dislodged and also goes with the polishings (bran). In addition to the scraping procedure the grain is also polished with rubbers in passing through the polisher. At the bottom of the rice polisher there are two exit tubes. The white polished rice emerges from the polisher through one of these exit tubes and the rice bran through

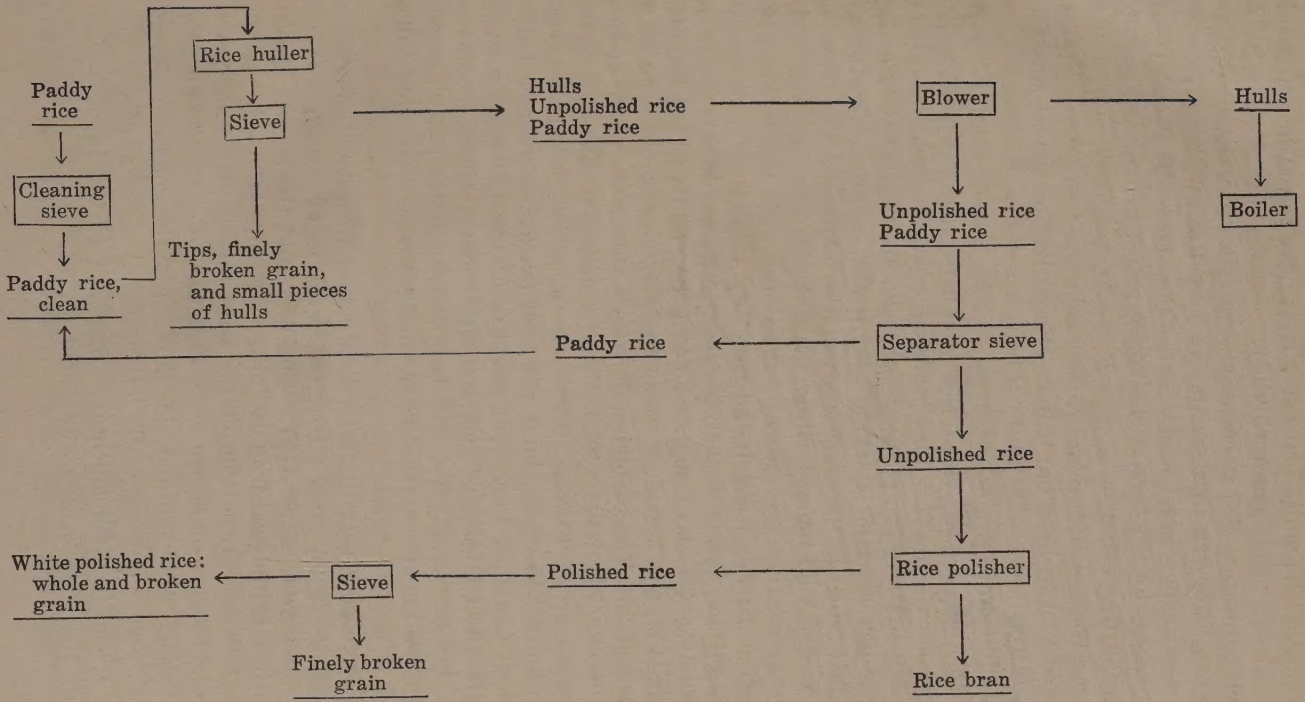

FIG. 1. Outline showing Philippine process of milling rice.

Rice-mill products: Polished rice, hulls, bran, and finely broken grain; also unpolished rice when desired.

the other. The white polished rice is next sieved to remove the very small broken grain (binlid).

The milling of rice is really a very clean process. From the time the paddy rice enters the mill until the polished rice and rice bran emerge from the mill these rice-mill products are not handled by laborers. The whole process is carried on automatically by machinery.

For power many mills have a steam engine and use the rice hulls as fuel to heat the boiler. Recently, however, some mills have introduced oil-burning engines.

In addition to the power house the four other essential parts of a rice mill are the rice huller, the blower, the separator, and the polisher. The rice huller consists of two iron disks. One is placed just above the other and the two are separated by a very small space. Artificial stone covers the lower surface of the top disk and the upper surface of the bottom disk. The top disk remains stationary while the bottom disk revolves. The whole apparatus is arranged so that the distance between the two stone surfaces can be adjusted by means of hand wheels which raise or lower the bottom disk. The paddy rice is poured into the rice huller through a hole in the middle of the top disk and falls on the lower revolving disk which throws it away in all directions. The revolving disk then grinds the grain around and breaks the hulls. The distance between the two disks should be arranged very exactly as otherwise the rice kernel may be crushed or the hulls not well broken. The rice huller is one of the most important parts of a rice mill since upon it depends the quantity of rice obtained from a given amount of whole grain. In Plate 4, fig. 1, is shown a rice huller opened and the two stone surfaces exposed, fig. 2 shows the rice huller closed.

The rice polisher (Plate 5) is a rather ingenious apparatus. It consists simply of an inverted frustum of a cone (1) set inside of a wire screen (2). The cone and the screen are inclosed in a cylindrical iron container. Before taking the photograph (Plate 5) a portion of the wire screen and a portion of the outside iron container were removed to show the abrasive cone inside. The top and side surface of the cone are covered with an abrasive prepared by mixing small pieces of emery with water glass (sodium silicate). Attached to the inner (cone) side of the wire screen and some distance apart are several

vertical rubber strips (3). The cone, supported by a main shaft, is made to rotate rather rapidly. For a medium-sized cone the rate is about 300 to 400 revolutions per minute. A stream of unpolished rice is allowed to fall on top of the cone. In descending through the polisher the grain (rice kernel) is whirled around in the space between the cone and the screen. The abrasive on the cone scrapes the surface of the grain, while the rubber strips, on the screen, polish the grain. The white grain, scraped and polished, emerges from the opening at the bottom of the apparatus, while the bulk of the scrapings (polishings or bran) passes through the wire screen. The bran which thus accumulates outside the screen is pushed, by a rotating slide, to an exit tube where it falls out.

A tube, placed at the side of the polisher, connects the space outside the screen with an exhaust fan. The fan draws a current of air through the screen. This air current prevents the polished rice from getting too hot and also removes most of the very fine bran dust that tends to adhere to the polished rice.

The degree of scraping the grain depends upon the adjustment of the cone. By lowering the cone the space between the cone and screen is made smaller and the progress of the grain through the polisher is retarded. The grain thus gets a more thorough scraping. By means of adjustment screws the rubber strips on the wire screen may be projected inward toward the cone. This also retards the progress of the grain, giving it a more thorough polishing and scraping.

In removing hulls from the paddy rice (hulling process) some of the rice kernels are broken. These broken kernels are passed through the rice polisher with the whole kernels. When the polished rice is sieved the larger pieces of broken polished rice remain with the unbroken polished rice while the very small pieces (binlid) together with some bran are removed. Small pieces of grain are usually sold as chicken food or used for making starch. Millers usually do not keep an accurate account of this stock which is comparatively small. The small pieces of broken polished rice serve as a good material for fermentation and so this kind of rice (brewer's rice) may be used for making fermented beverages. In Japan the manufacture of saké from rice is an old established industry.

In the Philippines the rice sold in the markets, stores, and tiendas is usually a mixture of the whole and partly broken

polished rice. The millers do not ordinarily separate this mixture.

In isolated districts in the Philippines miniature rice mills, commonly known in Tagalog as kiskisan, are sometimes used for milling small amounts of rice. In these mills the separation of bran and hulls is usually not very complete and consequently a low grade of bran, unsuitable for edible purposes, is obtained. In order to ascertain if the grain has been milled properly and the fresh bran is not diluted with hulls the bran should be tested as explained later.

Results in Philippine rice mills.—In milling rice the quantity and quality of the finished product depend upon the method of milling, the efficiency of the mill machinery, the variety of rice milled, and the condition of the rice before milling. During the process of milling some lots of rice break up to a much greater extent than others. The quantity and quality of the polished rice are therefore quite variable. In order to get a product of approximate average grade it is a very common practice in the Philippines to mix different varieties of rice before milling. However, one may occasionally visit a mill when they are running only one variety.

The results of milling rice in some Philippine mills are given in Table 3. The day these samples were taken the mills we visited happened to be running the macan variety of rice except mills numbered 1, 10, and 12 which were milling the elon-elon variety and No. 13 which was milling mixed varieties ("ordinario" rice).

As shown by the data the moisture content of the paddy (unhulled) rice varied somewhat due to the conditions and time allowed for curing and storing the paddy rice before milling. The average moisture content of these fourteen samples was 9.83 per cent.

Assuming that the paddy rice has been cured properly and is in suitable condition for milling then data on the rice-mill products, as recorded in Table 3, afford a convenient means for checking up the efficiency of the principal mill machinery—the rice huller, blower, separator, and polisher.

The lots of paddy rice milled in all of the fourteen mills did not vary greatly in moisture content and appeared to have about the same good physical condition. It would seem that the results obtained in the different mills are comparable.

TABLE 3.—*Results in some Philippine rice mills.*

Quality of mill products.	Mill.							
	1	2	3	4	5	6	7	8
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Paddy rice: Moisture	11.02	9.90	10.01	9.63	9.62	9.49	9.69	9.93
Unpolished rice:								
Paddy rice	0.10	0.26	0.06	0.04	0.04	0.05	0.15	0.73
Hulls	0.02			0.01	0.07			
Fragments of stones	0.04	0.02	0.01		0.09	0.07	0.05	0.06
Whole grains	89.60	96.70	92.50	97.60	78.00	89.90	84.90	95.10
Broken grains	10.24	3.02	7.43	2.35	21.80	9.98	14.90	4.11
Rice bran: Moisture	8.69	8.68	8.07	8.48	8.15	8.31	8.05	7.75
Rice bran (sieved, 30 mesh):								
Fine bran	84.00	83.50	82.00	82.00	84.70	70.70	89.50	85.50
Coarse material	16.00	16.50	18.00	18.00	15.30	29.30	10.50	14.50
Polished rice, finished product:								
Whole grains	75.80	89.50	85.80	84.00	76.50	84.40	67.50	74.90
Broken grains	24.20	10.50	14.20	16.00	23.50	15.60	32.50	25.10
Variety of rice [a]	Elon-elon.	Macan.	Macan.	Macan.	Macan.	Macan.	Macan.	Macan.

[a] These samples of rice-mill products were collected during the dry season on a clear hot day, April 17, 1933.

TABLE 3.—*Results in some Philippine rice mills*—Continued.

Quality of mill products.	Mill.							
	9[b]	10[c]	10[d]	11[c]	11[d]	12	13	14
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Paddy rice: Moisture	9.15	9.89	----------	9.88	----------	9.25	10.46	9.65
Unpolished rice:								
Paddy rice	0.03	0.29	----------	0.01	----------	0.01	0.03	0.23
Hulls	0.02	0.02	----------	0.01	----------	0.01	0.01	0.30
Fragments of stones	0.03	0.05	----------	0.13	----------	----------	0.16	0.03
Whole grains	82.90	89.60	----------	87.60	----------	83.20	86.30	91.40
Broken grains	17.02	10.04	----------	12.25	----------	16.78	13.50	8.04
Rice bran: Moisture	8.20	8.03	8.30	8.66	8.14	8.10	8.36	8.44
Rice bran (sieved, 30 mesh):								
Fine bran	86.00	87.50	81.00	90.00	83.50	95.00	86.50	85.00
Coarse material	14.00	12.50	19.00	10.00	16.50	5.00	13.50	15.00
Polished rice, finished product:								
Whole grains	68.10	63.30	----------	67.50	----------	79.30	79.40	79.90
Broken grains	31.90	36.70	----------	32.50	----------	20.70	20.60	20.10
Variety of rice	Macan.	Elon-elon.	----------	Macan.	----------	Elon-elon.	Mixed.	Macan.

[b] In this mill the rice was polished twice with the same polisher. [c] This mill had two polishers. [d] Results from the second polisher.

The unpolished rice contained a very small amount of foreign matter such as paddy rice, hulls, and fragments of stones. The amount of this foreign matter was determined by taking a 200-gram sample of the unpolished rice and carefully separating out, by hand, the individual foreign matter which was then weighed on a chemical balance. The weights obtained divided by 2 gave the percentages.

Samples of unpolished rice from most of the mills contained only a very small amount of rice hulls. This showed that the blowers were working very well. The unpolished rice also had very little paddy (unhulled) rice, showing that the separators were operating very efficiently.

The percentage of broken grains in the unpolished rice was determined by taking a 100-gram sample and separating, by hand, the whole grains which were weighed. The weight of the whole grains was then added to the total weight of the foreign matter (paddy rice, hulls, and stones). Subtracting this sum from 100 gave the percentage of broken grains.

In mills 2 and 4, the unpolished rice contained only a very small amount of broken grains. This indicated that the rice huller was working efficiently in these mills. The unpolished rice in mill 5, however, contained a considerable amount of broken grains indicating that the huller was working poorly and was probably adjusted too tightly.

The average moisture content of all the samples of rice bran was 8.28 per cent, which is 1.55 per cent less than the average for the paddy rice. During the polishing process the bran is heated and loses moisture, consequently the moisture content of the bran is less than that of the paddy rice.

We sieved the rice bran, obtained from these mills, through a 30-mesh sieve and determined the percentage of fine bran which passed through the sieve and also the percentage of coarse material retained by the sieve. The average percentage of fine bran was 84.67 and of the coarse material, 15.33. Before entering the polisher the rice kernel (unpolished rice) contained only a small amount of foreign matter, consequently the coarse material in the bran consisted almost entirely of fragments of rice kernels.

Bran from mill 12 contained less coarse material than bran from the other mills. Evidently the polisher in this mill had a very good screen as only a small amount of finely broken rice kernels passed through the screen with the bran. The polisher in mill 6 probably had a very poor screen with holes in it as a

considerable amount of broken rice kernels was found in the bran which passed through the screen.

In mills which had two polishers the bran from the second polisher was slightly lighter in color than the bran from the first polisher because it contained more starchy material. The bran from the second polisher also had more finely broken rice kernels than bran from the first polisher. Probably the second polisher was adjusted somewhat tighter than the first polisher.

The amount of whole and broken grains in the polished rice (finished product) was determined by taking a 100-gram sample and separating, by hand, the whole grains from the broken grains. These different lots were then weighed to get the percentages.

The polished rice from mills 9, 10, and 11, contained more broken grains than the polished rice from the other mills. In these three mills the grain was polished twice and each time the rice went through the polisher some of the grains were broken. Mill 2 produced a polished rice which had the least amount of broken grains. The polished rice from this mill was slightly darker in color than the polished rice from the other mills, indicating that this rice was not polished as much as the others which appeared to have had about the same degree of polishing.

According to our results the macan variety of rice mills better than the elon-elon, because the macan gave less broken grains than the elon-elon. Philippine rice millers, however, believe that the elon-elon is the better milling rice. Mr. G. M. Reyes, of the Bureau of Science, examined our samples of elon-elon and found they contained about 5 to 8 per cent of varieties which were not elon-elon. This would, perhaps, account for the fact that the elon-elon did not mill as well as we expected.

In the Philippine process of milling rice the grain is broken in both the rice huller and polisher as shown by the data given in Table 4. The breakage may be about the same in each machine or it may be greater in either the huller or polisher.

In mill 3 the amount of grains broken in the polisher was very nearly the same as in the huller. In mill 4 the polisher broke considerably more grains than the huller while in mill 5 the breakage was much greater in the huller than in the polisher. In calculating these results the percentage of grains broken in the polisher was determined by subtracting the percentage of broken grains in the unpolished rice from the percentage of broken grains found in the polished rice (finished product).

These percentage figures are, of course, only approximate as, during the milling process, some grains will be crushed or broken into fragments of rice kernels which were not considered in the breakage calculation. The results given in Table 4, do show, however, where the breakage of grains occurs mostly in the different mills. By adjusting more exactly the particular machine which causes most of the breakage the amount of broken rice grains may be considerably decreased. Rice that contains a considerable quantity of broken grains sells for a lower price than rice which has only a small amount of broken grains.

TABLE 4.—*Breakage of Philippine rice grains (macan variety) in rice huller and polisher.*

Mill.	Grains broken in huller.	Grains broken in polisher.	Polished rice (finished product).	
			Broken grains.	Whole grains.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
2	3.02	7.48	10.50	89.50
3	7.43	6.77	14.20	85.80
4	2.35	13.65	16.00	84.00
5	21.80	1.70	23.50	76.50
6	9.98	5.62	15.60	84.40
7	14.90	17.60	32.50	67.50
8	4.11	20.99	25.10	74.90
9	17.02	14.88	31.90	68.10
11	12.25	20.25	32.50	67.50
14	8.04	12.06	20.10	79.90
Average	10.09	12.10	22.19	77.81

In the Philippines the rice is graded by observation and not by machines. A dealer simply takes a handful of polished rice, spreads it over his open hand and estimates approximately the proportion of broken grains and the degree of polishing. Some dealers are said to be quite expert in grading. However, occasionally you may find in one market a sample of second-class rice which is better than a first-class sample in another market. So the grades sold in different markets are not always uniform.

The Philippine process of milling rice is quite different from that used in the United States.[10] In the Philippines the scraping and polishing of the grain are done in one machine—the rice polisher. In the United States these two operations are per-

[10] Wise, F. B., and A. W. Broomell, U. S. Dept. Agr. Bull. 330 (1916). Fraps, G. S., Texas Agr. Exp. Sta. Bull. 191 (1916).

formed in separate machines. Again, in the United States it is often customary to coat the polished rice with glucose and talc which gives the grain a brighter luster. The polished rice is then graded mechanically into grains of different sizes. These extra operations are not performed in the Philippines.

TABLE 5.—*Average production of whole and broken polished rice grains in Philippine and American rice mills.*

Kind of rice grains.	Variety of polished rice.					
	Philippine mills.				American mills.[a]	
	Rice polished once.		Rice polished twice.		Honduras.	Japan.
	Macan.	Elon-elon.	Macan.	Elon-elon.		
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Whole grains	80.31	77.55	67.80	63.30	51.69	82.57
Broken grains	19.69	22.45	32.20	36.70	48.31	17.43
Total	100.00	100.00	100.00	100.00	100.00	100.00

[a] Wise, F. B., and A. W. Broomell, U. S. Dept. Agr. Bull. 330 (1916).

In Table 5 is given a comparison of the amount of whole and broken polished rice grains obtained during the milling of rice in Philippine and American mills. As shown by the data for the elon-elon and macan varieties of Philippine rice the percentage of whole grains produced in the Philippine mills compares very favorably with the best results obtained in the American mills.

TABLE 6.—*Yields in Philippine mills of polished rice, bran, and hulls from paddy rice.*

Constituent.	Mill 15.	Mill 16.	Average.
	Per cent.	*Per cent.*	*Per cent.*
Polished rice	64.8	66.1	65.45
Rice bran[a] (not sieved)	6.8	6.2	6.50
Rice hulls[b]	28.4	27.7	28.05
Total	100.0	100.0	100.00

[a] Contains some finely broken grain (binlid).

[b] Data for the hulls include the percentage of finely broken grain produced in the rice huller.

Yields of Philippine rice-mill products.—The yield of polished rice varies somewhat. Some varieties give a slightly higher yield than others. In the larger mills they generally estimate

that 100 cavanes (44 kilos each) of whole, mixed rice will yield roughly about 50 cavanes (57 kilos each) of milled polished rice. In Table 6 are given the yields of polished rice, bran, and hulls obtained from paddy rice in two of the large Philippine mills. The average of the results obtained in these mills is about the average of Philippine milling practice. As shown by the data (Table 6) there is a slight variation in the yields. For these particular runs mill 15 gave a slightly lower percentage of polished rice but a higher percentage of bran and hulls than mill 16. By adjusting the polishers to get a more thorough scraping of the grain there is obtained a very white grade of rice with somewhat less yield while the amount of bran is slightly increased.

Philippine rice, when milled, yields an average of 6.50 per cent of rice bran. When sieved, the crude bran gives 84.67 per cent of fine bran and 15.33 per cent of coarse material. The proportion of fine bran and coarse material in 6.50 per cent of rice bran (not sieved) would be as follows:

$$6.50 \times 0.8467 = 5.50 \text{ per cent fine bran.}$$
$$6.50 \times 0.1533 = 1.00 \text{ per cent coarse material.}$$

The estimated average yearly production of Philippine rice-mill products is given in Table 7. As shown by the data there is a very considerable amount of fine rice bran produced during the year.

TABLE 7.—*Average yearly production of Philippine rice-mill products.*

Rice-mill products.	Yields from paddy rice.	Average yearly production.[a]
	Per cent.	*Metric tons.*
Polished rice	65.45	1,323,799
Rice bran (sieved, 30 mesh):		
Fine bran	5.50	111,316
Coarse material	1.00	20,154
Hulls	28.05	567,342
Total	100.00	2,022,611

[a] Average yearly production of paddy rice is 2,022,611 metric tons (Table 1).

For a medium-sized Philippine mill running about ten hours a day during the milling season the average amount of rice milled is about 250 cavanes, or 11,000 kilos, a day. Data showing the daily production of mill products from a medium-sized mill are given in Table 8.

TABLE 8.—*Daily production of rice-mill products from a medium-sized Philippine mill.*

Mill products.	Daily production. kg.
Polished rice	7,199.5
Rice bran (sieved, 30 mesh):[a]	
Fine bran	605.4
Coarse material	109.6
Hulls	3,085.5
Total	11,000.0

[a] The crude rice bran is usually not separated by sieving into fine bran and coarse material.

RICE STARCH

Although rice starch is not strictly a rice-mill product it may be well to mention it since it is an important commercial product made from polished rice. Rice contains about 78 per cent of starch. This is a larger percentage than is contained in any other starchy material, such as wheat, maize, or potatoes. Various authorities [11] give a very good description of the manufacture of starch from rice. According to Thorpe—

> The demand for rice starch has grown chiefly because of its suitability for laundry use, and this in turn is due entirely to the fact that the rice starch granule is considerably smaller than that of any other commercial starch. When made with boiling water, too, the resulting mucilage is better adapted for "starching" than other starches.

Rice starch is used commercially for various purposes such as laundering, preparing foods, making paste, and making medicinal tablets. It is also employed extensively in the cosmetic industry for making face powders. In addition to the perfume, the principal characteristics of a good face powder are color, texture, and perfect adherence to the skin. The latter qualities impart the appearance and finish. According to Poucher,[12] the peachlike finish given to the skin by face powders is best obtained by the use of rice starch. Other starches, especially maize, are employed in cheaper powders. The particles of rice starch are much finer than those of any other cereal and consequently there is a distinct preference for rice powders. Parisian manufacturers of cosmetics rate these powders very highly and

[11] Thorpe, E., A Dictionary of Applied Chemistry 6 (1926) 374. Rehwald, F., and C. Salter, Starch-making (1926) 169.

[12] Perfumes, Cosmetics, and Soaps 2 (1929) 478 and 480.

in comparing the qualities of rice powder with other powders they find the rice powder to be by far the least harmful to the skin and much smoother.

RICE HULLS

In milling rice the hulls are obtained as a by-product. They are light in weight, neutral in odor, and have a slow combustibility. They are used for packing hygroscopic materials to prevent moisture absorption; filtering and percolating; for insulation, making insect powder, and various other purposes.

In the Philippines the rice hulls are generally used as fuel in the rice mills. They are also employed in hatching duck eggs[13] and in burning wood for charcoal.

TABLE 9.—*Analysis of Philippine rice hulls.*[a]

Constituent.	Variety of rice hulls.	
	Ramai.	Macan.
	Per cent.	*Per cent.*
Moisture	7.65	6.77
Fat (ether extract)	0.62	0.63
Protein	1.75	1.97
Crude fiber	34.97	38.92
Ash	22.29	21.69
Carbohydrates by difference	32.72	30.02
Total	100.00	100.00

[a] Analyses made by Mr. H. Taguibao, of the Bureau of Science.

In Table 9 are given analyses of rice hulls from two varieties of Philippine rice (ramai and macan). As shown by the data the hulls consist largely of crude fiber and also have a rather high ash content. Since the ash (Table 10) consists principally of silica the hulls have a very low nutritive value. It is generally believed that the hulls have an irritating effect[14] upon the stomach and intestines of animals.

On account of their very high silica content the ashes of rice hulls, when finely powdered, serve as a good polishing powder. They should also be useful for making polishing pastes and scouring soaps.

[13] Burgos, C. X., Philip. Agr. Rev. 27 (1924) 87.
[14] Fraps, G. S., Texas Agr. Exp. Sta. Bull. 191 (1916).

TABLE 10.—*Analysis of the ash of rice hulls.*[a]

Constituent.	Per cent.
Silica oxide	95.49
Iron and alumina oxides	0.94
Calcium oxide	0.86
Magnesium oxide	0.28
Phosphorus as P_2O_5	0.36
Sodium and potassium oxides	1.58
Total	99.51

[a] Journ. Indus. Eng. Chem. News Ed. 9 (1931) 57.

Rice hulls have been found to be useful for making an edible rice cellulose. Harding[15] states:

A recent advance in food technology is the development of a process of recovery of an edible cellulose from the hulls of rice and other cereals. Cellulose is a natural constituent of practically all vegetable foods and is really an essential dietary constituent. By adding bulk and roughage to the intestinal contents normal elimination is promoted and constipation largely prevented.

In the development of a new ready-to-serve breakfast food milled rice was found to be the most desirable cereal base. Because of the low cellulose content of milled rice it was decided to reënforce the roughage content of the finished cereal by additions of a pure cellulose of suitable physical form. It was found that a satisfactory pure edible cellulose could be prepared from the hull of the rice, thus making the breakfast food an all-rice product. The cellulose of the hull is first isolated in a semifibrous form by a strong soda cook. A hydration treatment then reduces it to the proper physical form for use as an edible material.

A large plant for the production of this new form of pure cellulose has been in operation for some time. It is located at Lake Charles, Louisiana, adjacent to the largest rice mill in the world.

Rice cellulose as prepared for food roughage is a light, somewhat fluffy, fine, mealy material. It has a light cream color, but is easily bleached white if desired. It is odorless and tasteless. It has a mealy feel in the mouth, and although not intended to be eaten straight, when well moistened with saliva, can be swallowed without difficulty or irritation. Its ash content has been reduced to 1.0 per cent or less, although the original raw material contains about 18 per cent of ash that is largely insoluble silica. The washed product from the alkaline digestion may run as high as 99 per cent alpha-cellulose. In the finished product a part of the original compound or normal celluloses has been converted to simpler hydrated celluloses; but the freedom from impurities of non-cellulosic character entitles it to be called a practically pure cellulose.

POLISHED AND UNPOLISHED RICE

After passing the paddy (unhulled) rice through the rice huller to remove the hulls the unpolished (hulled) rice then

[15] Journ. Indus. Eng. Chem. 20 (1928) 310.

goes through the polisher. There are several reasons for polishing rice. Polished rice has a very clean, white, and tasty appearance, whereas the unpolished rice is slightly colored and is not so attractive. Polished rice has much better keeping qualities than unpolished rice. The unpolished rice loses its flavor in a tropical climate because the fats in it become rancid. Again the unpolished rice has a tendency to get moldy and become infested with weevils and other insects, which destroy the outer mealy layer of the grain. This is the reason why the wholesale rice dealers are reluctant to handle unpolished rice. Polished rice can be handled without commercial hazard.

Photographs of the paddy rice, unpolished, and polished rice of two varieties (ramai, figs. 1, 2, 3; and elon-elon, figs. 4, 5, 6) are given in Plate 6. The paddy rice of the ramai variety, fig. 1, has a shape somewhat different from that of the elon-elon, fig. 4. Both paddy grains have ridges which are also seen in the unpolished rice, figs. 2 and 5, but not in the polished rice, figs. 3 and 6. During the polishing process the brown seed coat of the rice kernel is removed, the ridges worn down, and the surface then scraped and smoothed over. This gives the surface of the polished rice a whiter and cleaner appearance than that of the unpolished rice. The germ of the grain observed in the indentation on the unpolished rice, figs. 2 and 5, is also removed during the polishing and is not seen in the photographs of the polished rice, figs. 3 and 6.

Samples of unpolished rice of numerous Philippine varieties have been analyzed.[16] The results showed a slight variation in the percentages of fat, protein, crude fiber, ash, and carbohydrates.

TABLE 11.—*Analysis of polished and unpolished rice (Macan variety).*[a]

Constituent.	Polished rice.	Unpolished rice.
	Per cent.	*Per cent.*
Fat (ether extract)	1.21	3.00
Protein (N x 6.25)	8.66	9.22
Ash	0.65	1.57
Crude fiber	0.31	0.87
Carbohydrates by difference	89.17	85.34
Total	100.00	100.00

[a] Analyses made by Mr. H. Taguibao, of the Bureau of Science. Results calculated on a moisture-free basis.

[16] Wells, A. H., F. Agcaoili, and R. T. Feliciano, Philip. Journ. Sci. 20 (1922) 353.

Analyses of Philippine polished and unpolished rice are given in Table 11. At the time these samples were taken the mill was running the macan variety of rice. As shown by the data the unpolished rice, which still retains the seed coat and oily germ, contains somewhat more fat, protein, ash, and crude fiber than the polished rice. The polished rice, however, contains more starchy material (carbohydrates).

The effects of living on a diet composed largely of polished (highly milled) rice or unpolished (undermilled) rice are stated very clearly by Vedder and Feliciano:[17]

> Although medical authorities still differ with regard to a number of details concerning the etiology of beriberi, there is a very general consensus of opinion to the effect that beriberi is a deficiency disease, produced whenever, in the absence of an adequate mixed diet, highly milled rice is used as the main food staple, and that the disease can be prevented by the substitution of a sufficiently undermilled rice. The most striking illustration of this fact with which we are familiar is the case of the Philippine Scouts. For a number of years (1902–1909), while they were supplied with the best grade of highly milled rice, beriberi was the most important cause of admission to sick report for these native troops, the incidence often reaching as high as 10 per cent of the entire number (5,000). In 1910 the substitution of undermilled rice was made. Beriberi at once declined as a cause of admission and at the end of a year, when the substitution had been made universally effective, beriberi was completely eradicated. Since that time undermilled rice only has been furnished, and during all these years beriberi has completely ceased to appear among these troops, although they were living in the midst of a population where beriberi is very common. Similar results have been obtained in a number of civil institutions in the Philippines as well as in other countries.

The reason the unpolished rice is a preventative of beriberi is because it contains the antineuritic vitamin B_1, which prevents beriberi. During the polishing process, to produce white polished rice, most of the vitamins go with the rice bran which is removed from the grain as a by-product.

Vedder and Feliciano[18] carried out an elaborate investigation to determine a standard for unpolished rice which would prevent beriberi. Samples of unpolished rice from many varieties were analyzed and also fed to pigeons to determine their actual beriberi-producing potentialities. Pigeons were selected because they are even more susceptible to polyneuritis than the human race is to beriberi. As a result of their investigation

[17] Philip. Journ. Sci. 35 (1928) 351.
[18] Ibid.

they suggested, as tentative standards, the following chemical indices for beriberi-preventing rice:

> Any rice having 1.77 per cent of phosphorus pentoxide plus fat, but not less than 0.4 per cent phosphorus pentoxide; or any rice having not less than 0.62 per cent phosphorus pentoxide; or any rice having not less than 0.50 per cent phosphorus pentoxide and with at least 75 per cent of the external layers of the grain remaining.

Vedder and Feliciano also determined the effect of washing unpolished rice and found that for ten samples the average loss in phosphorus pentoxide was 0.25 per cent. Presumably the vitamin content of these rices was similarly reduced. They further state—

> Previous writers, including Schüffner and Kuenen and McCarrison and Norris, have shown that prolonged washing or soaking of the rice, prior to cooking, extracts and removes a considerable portion of its vitamin, and that an originally beriberi-preventing rice may be thus converted into a beriberi-producing rice. This is what would be expected, in view of the fact that the antiberiberi vitamin is very freely soluble in water . . . It is to obviate such difficulties as much as possible that we have recommended such a high standard for a beriberi-preventing rice. A lower standard would undoubtedly suffice if it were not for such factors as excessive washing, pressure cooking, and other procedures that cannot be foreseen; but the standard recommended at least provides a considerable margin of safety.

THE NUTRITIOUS PARTS OF THE RICE GRAIN (EMBRYO AND ALEURONE LAYER)

According to Vedder and Feliciano[19] the antineuritic vitamin B_1, the fat, and most of the phosphorus of the unpolished rice are undoubtedly contained chiefly in the embryo (germ) and the aleurone layer of the unpolished rice grain. Dr. J. K. Santos[20] of the Bureau of Science has recently investigated sections of polished and unpolished rice and made diagrams of these sections.

A diagram of a longitudinal section of the whole rice grain (Malagkit variety) is given in Plate 7, fig. 1. This diagram shows the embryo with its principal parts, the cotyl, plumule, and radicle.

A segment of a part (cotyl) of the rice grain embryo is given, by diagram, in Plate 7, fig. 2. As shown by the diagram this segment, which is characteristic of the whole embryo, contains

[19] Philip. Journ. Sci. 35 (1928) 354.
[20] Philip. Journ. Sci. (in press).

a considerable number of oil droplets as well as numerous protein granules. The oil droplets are identified by the pink to red color imparted by tincture of alkanna or the brown to black color given by osmic acid. The protein granules in these cells are identified by the yellow color given by an iodine solution.

A segment of a cross section of unpolished rice (Macan variety) is shown, by diagram, in Plate 7, fig. 3. This illustration shows the outside seed coat of the unpolished rice, the aleurone layer of cells beneath the seed coat, and the starch cells beneath the aleurone layer. The aleurone layer is the outermost layer of the endosperm or that part of the rice kernel that lies just beneath the seed coat. The aleurone cells in this layer contain protein granules and oil droplets. These oil droplets as well as those in the embryo comprise the rice oil which may be extracted from the bran. Starch granules in the cells beneath the aleurone layer are recognized by the familiar blue color imparted by an iodine solution. No oil droplets are found in these starch cells beneath the aleurone layer though protein granules are observed near the cell walls. The oily embryo and the aleurone layer are really the most nutritious parts of the rice grain since they contain the vitamins, the fats and also proteins.

In Plate 8 are given diagrams of the cross sections of unpolished rice (fig. 1) and polished rice (fig. 2) of the macan variety. During the polishing process the entire seed coat of the unpolished rice is removed. The embryo (germ) is also removed (Plate 6, figs. 3 and 6) as well as most of the aleurone layer of cells. Polished rice usually contains small portions (remnants) of the oily aleurone layer as shown by the diagram (Plate 8, fig. 2). The fatty oil contained in these portions of the aleurone layer becomes rancid when the polished rice is stored for some time and as a consequence the polished rice tends to lose its fresh flavor.

The degree of polishing determines how much of the aleurone layer remains with the polished rice. A highly polished rice contains very little of the aleurone layer. As suggested by Vedder and Feliciano and shown by the diagrams of Santos the polishing process removes from the rice grain the most nutritious parts which go with the rice bran (polishings).

RICE BRAN

After the paddy rice is hulled the unpolished (hulled) rice, which remains, is passed through the polisher to get white pol-

ished rice. In the Philippines the rice polishings, removed during the polishing process, are commonly called rice bran, tikitiki, or darak. This rice bran (polishings) comprises the seed coat, germ, and most of the outer (aleurone) layer of the rice kernel together with some of the starchy material beneath the aleurone layer. The rice bran contains the most nutritious parts of the rice grain for it has vitamins, fats, proteins, and the phosphorus ingredient, as well as some starchy material (carbohydrate).

Bran with rice hulls.—In making rice-bran (tikitiki) extract we find that a bran which is moisture free and contains at least 20 per cent fat gives an excellent product, so we have come to regard this kind of bran as one of standard quality.

In our inspection of Philippine rice mills we visited several where it was customary to mix ground rice hulls with the bran. As the hulls contain very little fat (less than 1 per cent, Table 9) this diluted bran would, of course, give a low fat content, less than 20 per cent.

The amount of ground hulls contained in diluted bran may be estimated approximately. Suppose a sample of diluted bran, when analyzed, gives only 15 per cent fat calculated on a moisture-free basis. How much genuine bran is in the diluted mixture? A sample containing only bran of high quality (100 per cent standard bran) has at least 20 per cent fat. The hulls may be considered roughly as having no fat. The approximate percentage of bran and hulls in the mixture is obtained by the following calculation:

$$\text{Percentage of bran} = \frac{100 \times 15}{20} = 75$$

$$\text{Percentage of hulls} = 100 - 75 \text{ or } 25$$

This sample of diluted bran consists of about 75 per cent rice bran and 25 per cent hulls or other foreign matter. This calculation is, of course, based upon the composition of a high-grade bran suitable for making excellent rice-bran extract; that is, a standard bran containing at least 20 per cent fat calculated on a moisture-free basis.

Santos [21] has recently made a microscopic study of rice bran. He found that rice hulls, when contained in the bran, may be identified as they present a characteristic appearance under the microscope. In plate 8, fig. 3, is given a microscopic view of a fragment of a rice hull showing two of the surface hairs.

[21] Philip. Journ. Sci. (in press).

Rice bran suitable for use as an edible product should not contain any rice hulls. The hulls contain about 21 per cent of ash which consists mostly of silica. As the silica has abrasive properties, quite likely the hulls have an irritating effect upon the stomach and intestines.

In milling rice bran intended for edible purposes the mill should have a very efficient blower which will remove practically all the rice hulls from the unpolished rice. In our investigation of Philippine rice mills we found that most of the mills had very good blowers.

In purchasing bran from a rice mill it is advisable to inspect the unpolished rice before it goes through the polisher. If the grain before polishing contains no hulls then the bran removed from the grain during the polishing process will also be free of hulls unless the bran has been purposely adulterated. The bran should be taken as it comes fresh from the polisher because millers often pile fresh bran on top of stale bran so that bran lying in heaps about the mill is not likely to be very fresh.

RICE OIL (FATS) IN RICE BRAN

Yield of rice oil.—In Table 12 are given the moisture and fatty oil content of rice bran obtained from some Philippine rice mills.

TABLE 12.—*Fat content of rice bran from Philippine mills.*

Mill.	Polisher No.	Variety of rice.	Moisture.	Fat.	Fat (moisture free).
			Per cent.	*Per cent.*	*Per cent.*
17	1	Mixed	8.2	19.7	21.5
17	2	do	8.3	17.8	19.4
18	1	Elon-elon	9.1	20.9	23.0
18	2	do	9.0	17.1	18.8
19	1	Macan	8.8	19.7	21.5
19	2	do	8.2	16.3	17.8
20	[a] 1	Elon-elon	8.4	19.7	21.6
21	[a] 1	Mixed	6.9	18.7	20.1
22	[a] 1	Lamio	6.4	19.3	20.6
23	[a] 1	Macan	6.1	20.7	22.0

[a] This mill had only one polisher.

Bran from the first polisher contains somewhat more fatty oil than bran from the second polisher. During the second polishing of the grain there is naturally a tendency to remove more of the interior starchy part of the grain beneath the outer

oily (aleurone) layer. The fat content of the bran will, of course, vary somewhat according to the degree of polishing. Calculated on a moisture-free basis bran from the first polisher contains over 21 per cent of fat. Where only one polisher is used the fat content of the bran is 20 per cent or more.

Composition of rice oil.—Recently the composition of rice oil obtained from the bran of two varieties of Philippine rice (hambas [22] and ramai [23]) was investigated.

The hambas rice is a lowland variety which grows fast but matures rather late. It has somewhat long grains that have an average length of 8.3 millimeters, an average width of 2.7 millimeters, and an average thickness of 1.9 millimeters. Ramai rice is also a lowland variety. It requires plenty of water for cultivation. Although it matures slowly it is the highest yielding variety in the Philippines. It has rather large grains which have an average length of 7.74 millimeters, an average width of 3.47 millimeters, and an average thickness of 2.23 millimeters. As an edible product the ramai rice is not as tasty as some varieties of rice that have smaller grains.

TABLE 13.—*Comparison of Philippine rice oil with other oils.*

Constituent.	Philippine oils.			American oils.	
	Rice (ramai).[a]	Rice (hambas).[b]	Peanut.[c]	Rice.[d]	Cotton seed.[e]
Glycerides of:					
Unsaturated acids—	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Oleic	45.3	45.6	53.9	41.0	35.2
Linolic	27.6	27.7	27.0	36.7	41.7
Saturated acids:					
Myristic	0.1	0.2	----	0.3	0.3
Palmitic	16.9	17.3	8.5	12.3	20.0
Stearic	2.6	1.8	3.6	1.8	2.0
Arachidic	0.5	0.7	3.4	0.5	0.6
Lignoceric	0.9	0.7	2.4	0.4	----
Unsaponifiable matter	4.0	4.0	0.3	4.6	----
Total	97.9	98.0	99.1	97.6	99.8

[a] Cruz, A. O., A. P. West, and V. B. Aragon, Philip. Journ. Sci. 48 (1932) 5.
[b] Cruz, A. O., A. P. West, and N. B. Mendiola, Philip. Journ. Sci. 47 (1932) 487.
[c] Cruz, A. O., and A. P. West, Philip. Journ. Sci. 46 (1931) 199.
[d] Jamieson, G. S., Journ. Oil and Fat Indus. 3 (1926) 256.
[e] Jamieson, G. S., and W. F. Baughman, Journ. Am. Chem. Soc. 42 (1920) 1197.

[22] Cruz, A. O., A. P. West, and N. B. Mendiola, Philip. Journ. Sci. 47 (1932) 487.

[23] Cruz, A. O., A. P. West, and V. B. Aragon, Philip. Journ. Sci. 48 (1932) 5.

The composition of rice oil from bran of the two varieties of Philippine rice (hambas and ramai), which have different sized grains, is given in Table 13. These oils are very nearly identical in composition and consist principally of glycerides of oleic, linolic, and palmitic acids. They are very similar to cottonseed and peanut oils.

Rice oil has a rather dark brown color with a greenish tinge. The color is somewhat undesirable because buyers of edible vegetable oils, such as coconut oil, usually prefer an oil which is very light in color.

Production of rice oil.—The difficulty in producing rice oil commercially is that the oil is not easily expressed from rice bran. Recently we tried to express oil from rice bran by using a hydraulic press in the coconut oil mill of the Spencer Kellogg & Sons in Manila. With a pressure of about 4,000 pounds, which is commonly employed for expressing coconut oil, practically no oil was obtained from the rice bran. Since these pressure experiments were tried out Mr. C. Boysen, of Spencer Kellogg & Sons, informed us that he once expressed the oil from rice bran by using a pressure of 8,000 pounds. This high pressure would, of course, be rather expensive for an ordinary commercial process.

With the aid of expeller copra cake we were, however, able to express oil from rice bran by using a pressure of only 4,000 pounds. Expeller copra cake is the oil cake which remains after a large part of the coconut oil has been expressed from the dried copra (coconut meat) in the expeller presses. This cake still contains considerable coconut oil varying from about 10 to 15 per cent and sometimes even more. In the Philippine coconut oil mills this expeller copra cake is subjected to a second pressing in hydraulic presses to recover more of the coconut oil. The hydraulic copra cake which remains after this second pressing usually contains only about 5 per cent of coconut oil.

By mixing expeller copra cake (two parts) with rice bran (one part) and subjecting the mixture to a pressure of 4,000 pounds in a hydraulic press a mixture of coconut and rice oils was obtained. In this experiment the coconut oil, contained in the copra cake, acts as a solvent to dissolve the oil in the rice bran. This dark-colored mixed oil had an iodine number of 32.35 (Hanus). Rice oil has an iodine number of 99.5 and coconut oil an iodine number of 9. The proportion of each of these oils contained in the mixture may be ascertained by

carrying out the following calculation in which X represents the percentage of rice oil and Y the percentage of coconut oil:

$$X + Y = 100$$
$$\frac{99.5\,X + 9Y}{100} = 32.35$$

This mixed oil consists of 25.8 per cent rice oil and 74.2 per cent coconut oil. Thus by utilizing the oil contained in expeller copra cake for its solvent effect the rice oil mixed with coconut oil may be obtained from rice bran by pressure.

The composition of the oil cake obtained from the mixture of expeller copra cake and rice bran is given in Table 14.

TABLE 14.—*Composition of oil cake from a mixture of expeller copra cake (2 parts) and rice bran (1 part).*[a]

Constituent.	Composition. Per cent.
Moisture	8.73
Protein (N X 6.25)	17.42
Ether extract (fat)	9.02
Ash	7.17
Crude fiber	6.51
Carbohydrates (by difference)	51.15
Total	100.00

[a] Analysis made by Mr. H. Taguibao, of the Bureau of Science.

Rice oil produced commercially by expression should be filtered thoroughly immediately after it is obtained from the bran. When allowed to remain in contact with vegetable tissue containing fat-splitting enzymes the rice oil decomposes very rapidly.

Another method of producing rice oil would be, of course, to extract the bran with solvents. According to Fraps [24] a plant was erected at Crowley, Louisiana, years ago for the purpose of extracting the fatty oil from rice bran. The importance of vitamins and the vitamin content of rice oil were not known at that time. The venture was not successful.

The decomposition (hydrolysis) of rice oil will be taken up later in connection with the deterioration of rice bran, and the vitamins in rice oil will be considered in the discussion of vitamins in rice bran.

[24] Texas Agr. Exp. Sta. Bull. 191 (1916) 36.

Kimm and Noguchi [25] made a qualitative investigation of the fatty oil in the embryo of the rice grain. They found that the embryo oil contains oleic, linolic, myristic, palmitic, stearic, and arachidic acids. As these compounds are also contained in the rice-bran oil the composition of the embryo oil resembles that of the rice oil in rice bran.

VITAMINS IN RICE BRAN

Rice bran contains the water-soluble vitamin B_1, which is the antineuritic vitamin that prevents polyneuritis in pigeons and beriberi in humans. The rice oil (fats) in rice bran contains the fat-soluble vitamins A and E. When irradiated, the rice oil also contains vitamin D.

Vitamin B_1.—The effects of feeding rice bran to pigeons ill with polyneuritis are shown very clearly by the photographs in Plate 9. A pigeon was fed by Dr. A. J. Hermano, of the Bureau of Science, on a ration deficient in vitamin B_1 until it developed polyneuritis (fig. 1). When given 0.5 gram of rice bran the pigeon recovered in one day and became normal (fig. 2).

Vitamin B_1 appears to be quite resistant to heat. We heated rice bran at a temperature of 105°C., for three hours. Doctor Hermano found that this heated bran cured pigeons of polyneuritis just as easily and quickly as the fresh bran.

McCollum and Simmonds [26] state that Jansen examined unhulled rice which had been stored for 100 years and found the rice had lost little or none of its antiberiberi property (vitamin B_1). From this it appears that the hull serves as an excellent protection for the vitamins contained in the rice kernel. Moreover vitamin B_1, under the proper conditions, has excellent keeping properties.

Kondo and Okamura [27] kept unpolished rice in sealed tin cans for several years and found the rice was not attacked by insects and there was little change in the physical and chemical properties.

Concerning the vitamin B complex Dutcher [28] says:

> Considerable work has been done to show that the vitamin B complex may consist of five or more fractions. The existence of the antineuritic fractions, B_1 has been established definitely and vitamin B_2 is recognized as

[25] Scientific Papers of the Institute of Physical and Chemical Research, Tokyo 21 (1933) 4.

[26] The Newer Knowledge of Nutrition (1929) 116.

[27] Journ. Sci. Agr. Soc. Japan (1929) 183.

[28] Journ. Chem. Ed. 9 (1932) 1366.

a definite entity. These vitamins are also known, in this country, as B and G respectively. Eddy and co-workers contend that a third factor (B_3) is necessary for growth in pigeons, while Miss Reader of London believes that there is a fourth fraction of the old B complex which is necessary for normal growth in the rat. Miss Chick, also of London, is of the opinion that she has obtained evidence that a fifth fraction exists which is necessary for rat growth and which differs from B_4 in stability.

Windaus and co-workers have just announced the isolation of the antineuritic fraction (B or B_1) in crystalline form. Using modifications of the methods used by Jansen and Donath, Seidell and Peters, two types of crystalline products were isolated, one as the hydrochloride and one as the picrolonate. He ascribes the tentative formula, $C_{12}H_{17}N_3OS$, to this highly potent crystalline product. This compound was active in daily doses of from 2 to 4 gamma (2/1000 to 4/1000 of a milligram). The most potent preparations reported previously were those of Jansen and Donath, which were active in doses of from 7 to 9 gamma daily.

Rice-bran (tikitiki) extract.—For a number of years the Bureau of Science has been making an extract of rice bran (tikitiki extract) which contains vitamin B_1 and is used extensively for the cure of infantile beriberi. During the year 1931, 50,974 bottles of tikitiki extract with a sales value of 35,681.80 pesos were prepared. Of this number, 4,087 valued at 2,860.90 pesos were sold and 46,887 bottles with a sales value of 32,820.90 pesos were furnished to the Office of the Public Welfare Commissioner for free distribution.

The present method [29] used by the Bureau of Science for making rice bran (tikitiki) extract is indicated by the following outline:

1. Select a good grade of rice bran. This is ascertained by making an ether extract of the bran to determine the amount of fat it contains. This should be about 20 per cent calculated on a moisture free basis. If the fat content is much lower than this it indicates that the bran contains ground rice hulls or other foreign matter which does not contain any fat or vitamins; or perhaps the bran has deteriorated due to attacks of insects.

2. Mix the rice bran (50 kilos) with 25 per cent ethyl, or grain, alcohol (150 liters) and allow the mixture to stand, with occasional stirring, for twenty-four hours.

Vitamin B_1 is very soluble in water. The alcohol which is added serves to prevent fermentation of the vegetable matter in the bran.

3. Pour off the clear liquid and pass the sediment through the press.

4. Combine the liquids obtained in step 3 and evaporate to a syrupy consistency under 1 centimeter pressure with maximum temperature of 75° C.

5. Add 95 per cent alcohol to residue in step 4 to precipitate inactive gummy substances.

[29] Wells, A. H., Philip. Journ. Sci. 19 (1921) 67.

6. Allow the gummy substances to settle for about twenty-four hours then decant off the supernatant liquid.

7. Evaporate the alcoholic solution with precautions observed in step 4 till the specific gravity of the syrup is brought to 1.32 at 28.5° C., which is about the usual temperature of the factory evaporating room.

8. This syrup is then passed through the supercentrifuge, heated to 80° C., and bottled immediately while hot. After sealing the stoppers with sealing wax the bottles are pasteurized at 62° C., for about a half hour.

This preparation is the finished product which is now ready to be used as a medicine for beriberi.

Mr. F. M. Yenko, who has charge of the tikitiki-extract plant in the Bureau of Science, finds that the yield of tikitiki extract from rice bran varies considerably depending upon the quality of the bran used in making the extract. A sack (50 kilos) of very high-grade bran may yield as much as 75 bottles (50 cubic centimeters each) of standard extract. A sack of low-grade bran, which contains a considerable quantity of broken rice kernels and rice hulls, may give only about 45 bottles. By selecting from a shipment only those sacks which contain bran of good quality rather high average yields of extract may be obtained. During the year 1932 Mr. Yenko obtained an average monthly production of 69 bottles of extract from one sack of bran. At this rate of production the potency of 1 cubic centimeter of extract is about equivalent to that of 14.5 grams of high-grade rice bran.

The Bureau of Science sells a 50-cubic-centimeter bottle of extract for 70 centavos (Philippine currency) or 35 cents (U. S. currency). The mail or freight charges are extra.

Hermano [30] standardized this extract and found that when 0.2 cubic centimeter is added daily to a basal ration deficient in vitamin B_1 the ration then contains sufficient vitamin B_1 to support a growing rat. Pigeons which had contracted polyneuritis were cured in one day when given an aqueous solution containing 0.0175 gram of the pure extract. In these experiments the pigeons were kept in cages which were covered with fine-mesh wire to prevent access of the flies known as *Pseudolyncha maura*. These flies transmit to pigeons a blood disease (*Haemoproteus columbae*) which may become so severe as to prove fatal.

Experiments were also made by Doctor Hermano to determine the relative potency of the standard tikitiki extract as compared with activated clay secured from the Bureau of Chemistry and

[30] Philip. Journ. Sci. (in press).

Soils in Washington. This activated clay serves as an international standard for vitamin B_1. It has a concentration such that 10 milligrams are equivalent to one unit of vitamin B_1. A unit is that amount of vitamin B_1 which, when fed as a daily allowance, gives a weekly increase of 3 grams in the weight of an albino rat during an experimental period of four to eight weeks. Experiments in curing pigeons of polyneuritis showed that 10 milligrams of activated clay (1 unit) gave the same results as 17.5 milligrams of standard tikitiki extract.

In Table 15 is given the analysis of an average sample of standard tikitiki extract made in the Bureau of Science.

TABLE 15.—*Analysis of standard rice bran (tikitiki) extract made in the Bureau of Science.*

Constituent.	Composition. Per cent.
Total solids	70.37
Phosphorus as P_2O_5	1.68
Ash	3.54
Reducing sugars before inversion	28.35
Reducing sugars after inversion	29.99
Nonreducing sugars	1.27
Nitrogen	1.21
Alkalinity of ash in 100 grams tikitiki extract (gram KOH)	0.34
Qualitative analysis of ash for basic and acidic radicals.	Ca, Mg, K, Na, Cl, and S.
Specific gravity of extract at 27.5° C.	1.3189

The standard rice bran extract made in the Bureau of Science is an extract of high quality which contains no gums as these are removed, at extra expense, in the process of manufacture. As shown by the standardization tests of Doctor Hermano this preparation is also a very potent extract.

Vitamin A (fat-soluble) in rice bran.—McCarrison [31] found in unhulled rice vitamin A which prevents eye afflictions. Hermano [32] fed albino rats on a ration deficient in vitamin A until they developed general ill health and the eye disease known as xerophthalmia. The basal ration was then supplemented daily with 0.2 cubic centimeter of the fatty oil contained in rice bran. After one week the eye disease was cured and in one more week the rats had recovered their health and were again normal.

[31] McCollum, E. V., and N. Simmonds, The Newer Knowledge of Nutrition (1929) 115.

[32] Philip. Journ. Sci. (in press).

Plate 9, fig. 3, shows an albino rat in bad health and suffering from vitamin A deficiency. Fig. 4 shows the same rat recovered and in normal condition. The fatty oil used in these experiments was an ether extract of rice bran. The extract was heated in an air bath at a temperature of 105° C., for three hours to remove traces of ether. Evidently heating the fatty oil did not destroy the vitamin.

Vitamin E (fat-soluble) in rice bran.—Hermano [33] tested the fatty oil contained in rice bran and found it gave positive results for vitamin E (fat-soluble) which prevents sterility. Concerning his experiments he states:

> Six pairs of healthy rats were mated in six different cages. They were fed with the basal ration deficient in vitamin E. Three pairs of the rats, 1, 2, 34, 35, 36, and 37, were fed with the basal ration deficient in vitamin E for about three to four months, and no litters were produced. After an interval of time as indicated by the point x (text fig. 1, charts I and VII) the basal ration was supplemented daily with 0.2 cubic centimeter of the ether extract of crude tikitiki (rice bran). The results of the addition were significant in that these three pairs produced seventeen young. The other three pairs, rats, 3, 4, 25, 26, 27, and 28, continued to be fed with basal ration deficient in vitamin E; and, though they appeared to be healthy and mature, they produced no litters (text fig. 2, charts II and VI). . . . The ether extract from crude rice bran possesses the anti-sterility property, vitamin E.

Vitamin D in irradiated rice oil.—In making Japanese saké wine the saké cake that remains as a residue contains some rice oil. Takahashi and Lim [34] extracted the rice oil from saké cake. The unsaponifiable matter in the rice oil was then removed and from this unsaponifiable matter they isolated a crystallized sterol which melted at 137° C. These sterol crystals were then exposed to ultraviolet light (irradiated). Takahashi and Lim found that these irradiated sterol crystals were antirachitic and, when fed to albino rats, could cure and prevent rickets. Evidently the sterol crystals, when irradiated, developed the antirachitic vitamin D.

Rice oil contains about 4 per cent of unsaponifiable matter (Table 13) which is a comparatively large amount. Since unsaponifiable matter consists largely of sterols it would seem quite likely that vitamin D is either contained in rice oil or may be developed in the oil by irradiation.

[33] Philip. Journ. Sci. 41 (1930) 387.
[34] Journ. Agri. Chem. Soc. Japan 6 (1930) 109.

Hermano [35] tested rice oil for vitamin D and found it gave negative results. He then exposed the oil for fifteen minutes to ultraviolet light and tested the irradiated oil. Albino rats were fed for about a month on a basal ration deficient in vitamin D until the rats developed symptoms of rickets. The joints in the hind legs became somewhat swollen and the rats moved rather slowly. The basal ration was then supplemented daily with an olive oil solution containing 0.003 gram of irradiated rice oil. After three weeks the rats became quite lively, walked well and the leg swellings disappeared. The rats were then killed and the tibia bones in the hind legs cleaned, treated properly, and photographed. The photographs showed considerable calcification in the bones. Photographs of the tibia bones from rats fed on the same ration, except that cod-liver oil was used in place of rice oil, showed somewhat more calcification. Perhaps if the rice oil had been irradiated somewhat longer it would have given results as good as the cod-liver oil. For when the rice oil was irradiated for periods of only 5 and 10 minutes the results were not as good as when it was irradiated for 15 minutes.

Chicken perosis.—When used in a uniform diet for growing chickens, as pointed out in a note published recently, [36] rice bran appears to be superior to wheat as preventative of perosis (deforming leg weakness) in chickens.

In the fall of 1929 the animal husbandry division of the Bureau of Animal Industry and the departments of poultry husbandry of several Southern and Southwestern state agricultural experiment stations organized an informal coöperative project for the purpose of comparing, on a weight-for-weight basis, different feeding stuffs when included in a so-called "uniform" diet for growing chickens. During the spring and summer of 1930 the following experiment stations used the "uniform" diet in some of their feeding experiments with the growing chicks; Kansas, Louisiana, New Mexico, Missouri, Texas, the U. S. Poultry Experiment Station, Glendale, Arizona, and the U. S. Animal Husbandry Experiment Farm, Beltsville, Maryland.

Several of the stations reported that when the "uniform" diet was fed to chicks kept in confinement a high percentage of them became afflicted with perosis (deforming leg weakness). One of the writers (W. M. G.), observed, however, that when 10 and 20 per cent of rice bran replaced equivalent amounts of wheat in the "uniform" diet, no cases of perosis occurred. . . .

[35] Philip. Journ. Sci. (in press).
[36] Science 74 (1931) 249.

Perosis, or deforming leg weakness, in chickens is a condition of dietary origin, in which the legs become deformed in various ways.

The superiority of the rice bran as reported in these experiments is quite likely due to some vitamin contained in it.

Commercial importance of vitamins in rice oil.—Rice oil contains the fat-soluble vitamins A and E; and, when irradiated, vitamin D is developed in the oil. Should the vitamin D content of rice oil be increased, with sufficient irradiation, to that of cod-liver oil then the rice oil may become an important nutritive substance. Possibly it could be used as a substitute for cod-liver oil. Rice oil has a bland, fatty taste and in this respect the oil is certainly more agreeable to take than cod-liver oil.

In the United States the use of vegetable oils, particularly coconut oil, in making margarine has increased very considerably in recent years. According to Snodgrass:[37]

> Since the war the vegetable fats, and in particular coconut oil, have continued to grow in popularity in this country until now the ratio of animal to vegetable fats used in margarine is almost the reverse of what it was before the war. Approximately 60 per cent of the ingredients are now of vegetable origin, and only 40 per cent animal fats. Coconut oil is far and away the most important single ingredient, . . . In 1925–26 more of it was used than of all the animal fats together and over a period of several years it has been more important than oleo oil and neutral lard combined. The only other vegetable fat used in appreciable quantities is cottonseed oil.

Coconut oil does not contain the fat-soluble vitamins[38] A, D, and E. Since rice oil contains the fat-soluble vitamins A and E it might serve as an important product for use in the margarine industry as the rice oil would supply the vitamins which are not contained in the coconut oil. Mixtures of coconut and rice oils should make a margarine more like natural butter than when coconut oil alone is used.

In producing rice oil for commercial purposes either bran fresh from the polisher may be used or, as explained later, bran which has been heated and properly preserved. The rice oil may be extracted from the bran by means of hot coconut oil. The rice oil may also be produced by expressing mixtures of rice bran and expeller copra cake or by expressing the rice bran alone.

Data on the colors of mixtures of coconut and rice oils are given in Table 16.

[37] Food Research Institute, Stanford University, California, Fats and Oils Studies, No. 2 (1928) 105.

[38] Sherman, H. C., and S. L. Smith, The vitamins (1931) 270, 296, 329, and 341.

TABLE 16.—*Color of mixtures of coconut and rice oils.*[a]

Sample.	Mixture.		Color.	
	Coconut oil.	Rice oil.	Red.	Yellow.
	Per cent.	*Per cent.*		
1	100		0.1	0.6
2	95	5	1.7	17.0
3	90	10	2.5	57.0
4	80	20	4.9	141.0
1–A	100		2.1	15.0
2–A	95	5	3.0	42.0
3–A	90	10	4.1	87.0
4–A	80	20	6.5	165.0

[a] In these tests the same sample of rice oil was used for making mixtures with the coconut oil samples 1 and 1–A.

Rice oil is very much darker in color than coconut oil. When rice oil is mixed with coconut oil in various proportions the color of the mixed oil is darker than that of the coconut oil alone. The color of the coconut oil and also that of the mixed oils was determined by means of a Wesson model, cabinet-type colorimeter made by the Emil Greiner Co.

For our tests we used two different samples of coconut oil. One sample (No. 1) was a water-white oil which had been decolorized [39] by treating successively with Kieselguhr, vegetable charcoal (suchar), and talcum powder. The other sample (No. 1–A) was a high-grade, light yellow, commercial oil. In determining the color of the coconut oil alone we followed the procedure adopted by the Conference of Coconut Oil Manufacturers of the Philippines (1924).

All samples will be read to a yellow base to be determined by adding the two whole red units, within whose limits the sample falls, and multiplying same by 3.

As this procedure does not apply to mixtures of rice and coconut oils we simply used enough of the standard glass plate colors (red and yellow) to match the color of the mixed oil.

The results (Table 16) show that, as the percentage of rice oil in the mixture increases, there is a much greater increase in the yellow hue than in the red. In making margarine [40] this should be an advantage. For by incorporating rice oil with

[39] Cruz, A. O., and A. P. West, Philip. Journ. Sci. 41 (1930) 53.

[40] Clayton, W., Margarine (1920) 35. Snodgrass, K., Margarine as a Butter Substitute (1930) 120.

the other emulsified ingredients there is a tendency for the resulting margarine to be somewhat colored by a natural coloring matter.

PROTEINS IN RICE BRAN

Proteins are complex substances containing combinations of amino acids. Numerous researches have been carried out to determine the biological value of the proteins contained in various foods of animal or vegetable origin. Experiments in feeding animals, usually albino rats, have shown that some proteins (meat proteins) contain in their make-up certain amino acids which are necessary for the normal maintenance and growth of the animal body. The most important of these amino acids are generally believed to be histidine, lysine, tryptophane, and cystine. The biological value of a protein seems to depend, in general, upon the amount of these particular amino acids which are contained in the protein. Inferior proteins are deficient in these important amino acids necessary for maintenance and growth.

Osborne, Van Slyke, Leavenworth, and Vinograd [41] investigated the hydrolytic products of the protein of the rice kernel. They summarized their results as follows:

> The partition of nitrogen among the products of hydrolysis of oryzenin, the chief protein of the endosperm of rice, was determined by the Van Slyke method. Compared with the endosperm proteins of wheat or maize, the protein of rice yields relatively much of each of the basic amino acids, arginine, and lysine, and comparatively little ammonia and non-amino nitrogen. In its general amino-acid make-up it more nearly resembles the majority of the proteins of animal tissues than do the proteins of maize or wheat. This may explain the extensive use of rice as an almost exclusive diet in spite of its low protein content.

In the process of polishing rice the embryo goes with the rice bran. Hamada [42] investigated a sample of rice embryo containing about 70 to 80 per cent of pure embryo. He isolated the protein, oryzenin, from the rice embryo and by hydrolysis estimated the amino nitrogen contained in it. The following results were obtained:

	Per cent.
Nitrogen:	
Monoamino	54.44
Diamino	35.68

[41] Journ. Biol. Chem. 22 (1915) 274.

[42] Journ. Chem. Soc. Japan 44 (1923) 68. Scientific Papers of the Institute of Physical and Chemical Research, Tokyo 4 No. 46 (1925) 22.

	Per cent.
Diamino nitrogen as:	
Arginine	20.04
Histidine	5.72
Lysine	9.12
Cystine	0.68

As shown by these data the protein of the rice embryo contains the important amino acids, histidine, lysine, and cystine. Since rice bran contains the rice embryo these amino acids are therefore contained in the proteins of the rice bran.

From his experiments Hamada concluded that the protein of the rice embryo has a high biological value comparing favorably with meat proteins. Subsequent feeding experiments proved this.

Rice bran contains not only the rice embryo but also some of the rice endosperm (white rice) that is, the interior part of the rice kernel. Jones and Gersdorff [43] investigated the proteins in white (polished) rice and also the proteins in commercial rice bran. They found that the proteins in the white (polished) rice contain the amino acids, histidine, lysine, tryptophane, cystine, arginine, and tyrosine. The proteins in the rice bran were tested for the amino acids, tryptophane, cystine and tyrosine which were found to be present.

As a result of these various investigations it appears that the proteins in rice bran contain the important amino acids (histidine, lysine, tryptophane, and cystine) necessary for maintenance and growth.

Dr. J. Marañon,[44] of the Bureau of Science, investigated the nitrogen distribution in Philippine rice bran by means of Hausmann's method as modified by Osborne.[45] The results are recorded in Tables 17 and 18. He found that the protein nitrogen is about 8 times the nonprotein (Table 17). Investigation of nonprotein nitrogen showed that it contains mostly nonbasic nitrogen. The protein nitrogen consists largely of nonbasic nitrogen but also has a considerable amount of basic nitrogen. The data for the protein nitrogen distribution were calculated by the difference between the results of the nitrogen distribution after hydrolysis (Table 18) and the values of the hydrolytic nonprotein products (Table 17). These results agree, in

[43] Journ. Biol. Chem. 74 (1927) 415. Mitchell and Hamilton, The Biochemistry of the Amino Acids (1929) 181.

[44] Philip. Journ. Sci. (in press).

[45] Gortner, R. A., Outlines of Biochemistry (1929) 331.

general, with those obtained by Hamada for he found in the protein of the rice embryo more monoamino (nonbasic) nitrogen than diamino (basic) nitrogen.

TABLE 17.—*Nitrogen distribution in Philippine rice bran.*

Kind of nitrogen.	Rice bran.		Results calculated on basis of total nitrogen. [a]
	Air dried.	Moisture free.	
	Per cent.	*Per cent.*	*Per cent.*
Nonprotein	0.229	0.259	11.439
(Water soluble)	(0.891)	(0.442)	(19.523)
Protein [b]	1.771	2.005	88.561
Total	2.000	2.264	100.000
Nonprotein nitrogen:			
Acid amide	0.034	0.038	1.678
Humin	0.019	0.021	0.927
Basic	0.027	0.031	1.369
Nonbasic	0.149	0.169	7.465
Total	0.229	0.259	11.439
Protein nitrogen (calculated):			
Acid amide	0.154	0.174	7.685
Humin	0.049	0.055	2.429
Basic	0.300	0.340	15.018
Nonbasic	1.212	1.372	60.601
Undetermined	0.056	0.064	2.828
Total	1.771	2.005	88.561

[a] Calculated on the moisture-free sample containing 2.264 per cent nitrogen.

[b] The protein nitrogen is the difference between the total nitrogen and the nonprotein nitrogen.

TABLE 18.—*Distribution of rice-bran nitrogen after acid hydrolysis.*

Kind of nitrogen.	Rice bran.		Results calculated on basis of total nitrogen. [a]
	Air dried.	Moisture free.	
	Per cent.	*Per cent.*	*Per cent.*
Acid amide	0.188	0.212	9.364
Humin	0.068	0.076	3.357
Basic	0.327	0.371	16.387
Nonbasic	1.361	1.541	68.065
Undetermined	0.056	0.064	2.827
Total	2.000	2.264	100.000

[a] Calculated on the moisture-free sample containing 2.264 per cent nitrogen.

The comparative nutritive value of the proteins contained in rice bran and soy beans has been investigated by Mitchell and

Villegas.[46] They determined the actual digestible nitrogen of the protein rations fed. On a 10 per cent protein ration the results seemed to show that there was no distinct difference between the protein of rice bran and soy beans. The protein of soy beans, unlike that of other vegetables, is similar to both meat and milk protein and seems to fulfill all physiologic requirements.[47] It would appear that the proteins in rice bran have a high biological value and, like soy-bean protein, compare favorably with meat proteins.

RICE BRAN LACKS GLUTEN

Concerning gluten Thorpe[48] states:

> Wheaten flour differs from that of all other cereals in that after it has been made into a dough with a little water, it is possible to wash out the starch, leaving a sticky adhesive brown or greyish-brown residue which consists mainly of protein. This is crude gluten: on drying it in a water-oven, a hard, brittle horny mass, not unlike glue, results, which has lost its power of becoming plastic when wetted, and strongly adheres to the substance on which it rests. At a higher temperature, the wet gluten expands greatly until the expansive force ruptures its vesicles.
>
> The flour of other cereals when washed in a similar way entirely disintegrates, leaving no protein residue. The physical properties of wheaten dough depend almost entirely on the gluten, which acts as a mechanical agency for binding the particles of starch and for entangling the carbon dioxide gas produced by the fermentation: in the oven, this gas expands, causing the dough to rise and the gluten to remain distended until the heat fixes it.

Tadokoro[49] studied the chemical properties of glutinous and nonglutinous rice and found they were quite different in various respects.

Rice does not contain gluten. The so-called glutinous rices contain a kind of sticky substance instead of true gluten.[50] When used alone rice bran, lacking gluten, does not make bread which will rise. However, when rice bran is mixed with wheat flour the combination makes a bread which rises nicely and has a good texture.

[46] Journ. Dairy Sci. 6 (1923) 222.

[47] Daniels, A. L., and N. B. Nichols, Journ. Biol. Chem. 32 (1917) 95. Osborne, T. B., and L. B. Mendel, Journ. Biol. Chem. 32 (1917) 375.

[48] A Dictionary of Applied Chemistry 3 (1928) 427.

[49] Journal College of Agriculture, Hokkaido Imperial University, Sapporo, Japan 16 (1926) 91.

[50] Copeland, E. B., Rice (1924) 326.

UNBALANCED MINERAL CONSTITUENTS

Kintner and Holt [51] studied equine osteomalacia (bone weakening) in the Philippines and found that the prevention of this disease depends on the feeding of a ration properly balanced in the important mineral constituents calcium oxide and phosphorus pentoxide. The ration should be so balanced that the calcium oxide-phosphorus pentoxide intake ratio is between 1 : 1 and 1 : 1.8. Where there is a deficiency in one of these mineral factors this balance may be attained by adding to the ration the required amount of the proper constituent.

Rice bran has a rather high ash content, containing about 10 per cent (Table 20). Analysis of the ash for calcium and phosphorus has been made by Mr. M. Tirona, formerly of the Bureau of Science. The following results were obtained:

	Per cent.
Phosphorus pentoxide (P_2O_5)	5.09
Calcium oxide (CaO)	0.06

As shown by these data the ratio between the calcium oxide and the phosphorus pentoxide is not well balanced as the percentage of phosphorus pentoxide is quite high in comparison with the percentage of lime, which is very low. The composition of the bran, in this respect, resembles that of polished rice which also contains a relatively high content of phosphorus as compared to lime. In feeding stock this unbalanced ratio could be corrected, in accordance with the suggestions of Kintner and Holt, by adding the proper amount of calcareous constituents to a rice-bran ration or to the drinking water.

According to Sherman [52] 0.45 gram of calcium (0.63 gram CaO) and 0.88 gram phosphorus (2.02 grams P_2O_5) fill the actual daily requirement for adult humans but this represents the minimum of actual need rather than the normal allowance. He considers that the normal allowance for phosphorus should be 50 per cent above the average minimum while for calcium it should be even greater. He estimates the optimum allowance to be 0.70 gram calcium (1.0 gram CaO) and 1.32 grams phosphorus (3.0 grams P_2O_5). The optimum calcium oxide-phosphorus pentoxide ratio is 1.0 : 3.0 according to these data.

Concerning the use of rice bran as an ingredient of human food this unbalanced calcium-phosphorus ratio is not a serious matter for people who live on a mixed diet. For this ratio could

[51] Philip. Journ. Sci. 49 (1932) 75.

[52] Chemistry of Food and Nutrition (1932) 291, 298, 512.

be balanced to a considerable extent by including suitable vegetables in the diet; that is, vegetables which have a high ash content and a relatively large amount of calcareous matter in the ash.

Marañon [53] has recently investigated the mineral constituents of a considerable number of edible Philippine plants. His results for a few of the very common vegetables sold in the local markets are given in Table 19.

As shown by the data (Table 19) these vegetables contain considerably more calcareous matter than the phosphoric ingredient. This unbalanced mineral ratio is just the opposite of that in rice bran. The addition of these vegetables to a ration containing rice bran would tend to balance the calcium-phosphorus ratio in the bran.

NUTRITIVE VALUE OF RICE BRAN

Rice bran as a cattle food.—Rice bran should have a comparatively high food value since it contains vitamins, proteins, and fats. These are the most nutritious constituents of the rice grain.

In Louisiana, Texas, and elsewhere in the southern United States rice bran (polishings) has been used in feeding experiments [54] with cattle. The results showed that fresh rice bran, which has a sweet odor, is somewhat better than corn or corn meal. However, if the bran becomes rancid, due to decomposition of the fat contained in it, the cattle do not like it. Cattle also do not care for rice bran that has been mixed with any considerable quantity of rice hulls. It is generally believed that bran which contains rice hulls is not suitable for use as an edible product.

Lush and Hale [55] fed cows with a mixture consisting of fresh rice bran (90 per cent) and cottonseed meal (10 per cent) and found that the ration had no effect upon the flavor of milk given by the cows. They concluded that fresh, non-rancid rice bran is a desirable and economical dairy food.

In the Philippines rice bran has served as cattle food for a number of years. When bran that is not fresh is used for feeding horses an old local custom is to mix the bran with molasses to neutralize the stale taste.

[53] Philip. Journ. Sci. (in press).
[54] U. S. Dept. Agr. Farmers' Bull. 412 (1910) 18.
[55] Texas Agr. Exp. Sta. Bull. 352 (1927) 22.

TABLE 19.—*Some common Philippine vegetables which have a comparati vely high calcium and low phosphorus content.*[a]

Name of plant.		Part of plant used.	Ash.	Phospho-rus (P_2O_5).	Calcium (CaO).	Ratio $CaO:P_2O_5$.
Scientific.	Common.					
			Per cent.	*Per cent.*	*Per cent.*	
Amaranthus paniculatus Linn	Kudiapa	Leaves and tops	18.69	1.40	3.67	1 : 0.4
Amaranthus viridis Linn	Kolitis (kalunai)	Leaves	19.64	1.99	3.63	1 : 0.5
Apium graveolens Linn	Celery (kinchai)	Leaves and petioles	14.71	1.12	2.45	1 : 0.5
Basella rubra Linn	Ceylon spinach (alugbati)	Leaves and tops	16.08	1.51	3.33	1 : 0.5
Beta vulgaris Mog	Beet (remolacha)	Leaves	22.40	1.27	3.17	1 : 0.4
Beta vulgaris Linn. var. *cicla* Linn	Swiss chard	do	20.27	0.73	3.14	1 : 0.2
Brassica chinensis Linn	Petsai (pechai)	Leaves and petioles	18.20	1.74	4.65	1 : 0.4
Brassica integrifolia (West) O. E. Schulz	Chinese mustard	do	18.94	1.90	3.30	1 : 0.6
Brassica oleracea Linn. var. *acephala* DC	Koles (kales)	Leaves	16.54	1.67	5.04	1 : 0.3
Capsicum frutescens Linn	Bird pepper (sili)	do	14.45	1.11	2.27	1 : 0.5
Colocasia esculentum (Linn.) Schott	Taro (gabi)	do	13.51	1.19	2.22	1 : 0.5
Coriandrum sativum Linn	Coriander (ongsoy)	Leaves and petioles	10.69	1.16	2.56	1 : 0.5
Lactuca sativa Linn	Lettuce (lechugas)	Leaves	17.55	1.60	2.78	1 : 0.6
Momordica charantia Linn	Amargoso (ampalaya)	do	18.77	1.87	4.36	1 : 0.3
Petroselium hortense Hoffm	Parsley (perejil)	do	15.90	1.29	2.79	1 : 0.5
Plantago major (L.) var. *asiatica* Decne	Japanese plantain	do	15.08	1.07	3.86	1 : 0.3
Psophocarpus tetragonolobus (Linn.) DC	Seguidillas	Young pods	7.74	0.24	1.37	1 : 0.2
Solanum nigrum Linn	Amantec	Leaves	12.08	1.23	3.68	1 : 0.3

[a] The percentages were calculated on the moisture-free sample.

Rice bran has a higher food value than ordinary hydraulic copra cake, which contains about 5 per cent of coconut oil. This is shown by the data given in Table 20. In calculating these food values one gram of carbohydrates, or proteins, was considered as giving 4.1 calories and one gram of fats 9.3 calories.

TABLE 20.—*Composition and food value of Philippine rice bran compared with hydraulic copra cake.*

Constituent.	Rice bran.[a]	Hydraulic copra cake.[b]	Mixture of equal parts of rice bran and hydraulic copra cake.
	Per cent.	*Per cent.*	*Per cent.*
Moisture	10.04	5.38	7.71
Fat	19.08	5.00	12.04
Protein	11.27	19.90	15.59
Ash	10.32	5.90	8.11
Crude fiber	8.67	9.50	9.08
Carbohydrates (by difference)	40.62	54.32	47.47
Total	100.00	100.00	100.00
Calories per kilo	3,902	3,508	3,705

[a] Analysis made by Mr. H. Taguibao, of the Bureau of Science.
[b] West, A. P., and W. H. Brown, Bull. Philip. Bur. Forestry 20 (1920) 100.

Copra cake is used considerably as cattle food and some buyers prefer a cake which has a somewhat higher fat content than is ordinarily contained in hydraulic copra cake. A mixture of hydraulic copra cake and rice bran in equal proportions gives a combination that has a higher food value than the copra cake alone, for it contains not only sufficient proteins and carbohydrates but more fat. Furthermore, the combination has the fat-soluble vitamins A and E, which are not contained in copra cake. For a cattle food this is a decided advantage since it tends to enrich the milk of the cattle in fat-soluble vitamins.

Rice bran as a human food.—Table 21 gives the composition and food value of Philippine rice bran (hambas variety) compared with wheat bran and flour.

As shown by the data (Table 21) rice bran has a much higher food value (calories) than either the wheat bran or the flours. This is due to the fact that the rice bran has a much higher fat content than the wheat bran or flours although the protein and carbohydrate contents are lower.

Recently the Bureau of Science has taken steps to popularize the use of rice bran as a human food. At the industrial exhibition held recently in Manila the Bureau gave an interesting

display of bread, cakes, and other bakery products made from rice bran. Miss Orosa has published a popular bulletin [56] on rice bran as a health food and how to cook it. This bulletin gives recipes for making rice-bran biscuits, fritters, croquettes, pudding, cookies, and many other tasty foods.

TABLE 21.—*Composition and food value of Philippine rice bran (hambas) compared with wheat bran and flour.*

Constituent.	Composition.				
	Bran.		Flour.		Mixture of rice bran (1 part) and wheat flour (3 parts).
	Rice.[a]	Wheat.[b]	Graham.[b]	Wheat.[b]	
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Moisture	10.04	10.91	7.73	9.93	9.96
Fat	19.08	5.03	1.79	0.92	5.46
Protein	11.27	14.84	15.33	13.74	13.12
Ash	10.32	5.59	1.32	0.52	2.97
Crude fiber	8.67	5.98	----------	----------	[c]2.17
Carbohydrates (by difference)	40.62	57.65	73.83	74.89	66.32
Total	100.00	100.00	100.00	100.00	100.00
Calories per kilo	3,902	3,440	3,822	3,719	3,765

[a] Analysis made by Mr. H. Taguibao, of the Bureau of Science.

[b] Leach, A. E., and A. L. Winton, Food Inspection and Analysis (1920) 320 and 322.

[c] This figure is only approximately correct since the crude fiber was not determined in the Graham and wheat flours. One gram of carbohydrates or proteins was calculated as giving 4.1 calories and 1 gram of fats 9.3 calories.

Some people do not fancy the natural flavor of rice bran. For such people the flavor may be toned down considerably by diluting the bran with wheat flour. A mixture of wheat flour (3 parts) and rice bran (1 part) makes a good combination for bakery products such as bread and cakes. This combination has a food value (Table 21) higher than that of wheat flour.

Rice bran, when used alone, lacks gluten and does not make bread which will rise. The addition of wheat flour serves not only to dilute the bran but also to supply the gluten necessary for making bread.

The bran flavor may be still further neutralized or entirely disguised by using other characteristic flavors, such as ginger, cinnamon, or chocolate. Bran cookies made with these flavors are very tasty and since they contain vitamins they are quite nutritious.

[56] Bu. Sci. Pop. Bull. 15 (1932).

Rice bran as a preventative of beriberi.—In the Philippines beriberi is a very common and fatal disease among the poorer classes who live on a diet that consists principally of polished rice and is deficient in vitamin B_1. The standard extract of rice bran (tikitiki extract), made in the Bureau of Science, is widely used and has given excellent results as a preventative or cure for beriberi.

According to Van Veen,[57] Jansen and Donath estimate that the amount of antineuritic vitamin B_1 contained in 30 grams of rice bran is probably more or less the quantity required for an adult per diem. This is just about equivalent to 11 level (not heaping) teaspoonfuls of bran or approximately 2 cubic centimeters of standard rice-bran extract (14.5 grams of high-grade bran make 1 cubic centimeter of extract).

In the Philippines more than 111,000 tons of fine rice bran are produced annually as a rice-mill by-product. Estimating the population of the Islands at 13,000,000, this is sufficient to supply each person daily with about 23.3 grams of fine rice bran. People who live on a mixed diet do not require the bran for its medicinal value so the annual production of rice bran is probably about sufficient for all the people who really need it and for others who would benefit by using it.

In a very few localities in the Philippines the people have for years been used to eating a kind of cake made from a mixture containing some fresh rice bran. If this use of rice bran as a human food could be popularized and people all over the Islands become accustomed to eating bakery products or other foods containing rice bran, then deaths from beriberi would be a rarity. It would not be necessary for the poorer classes to take extract of rice bran as a preventative or cure for beriberi.

DETERIORATION OF RICE BRAN

Insect infestation.—When rice bran, fresh from the polisher, is allowed to stand for a day or so the bran becomes infested with insects. Unhulled rice grains frequently carry insect eggs that have been deposited upon the grain in the field before the grain is brought to the mill. Again, insects breed freely in rice bran which accumulates about the mill. There is a Philippine ordinance which provides that rice mills shall be cleaned of all waste once a day but this regulation is not strictly enforced. We visited mills which were really very clean but there were

[57] Mededeelingen Van Den Dienst Der Volksgezondheid in Nederlandsch-Indie 20 II (1931) 1.

others which presented quite a different appearance. In the Philippines, as in the United States and other countries, insect infestation is one of the important problems connected with the milling industry.

W. Schultze,[58] formerly entomologist of the Bureau of Science, has identified the following insects which infest unpolished rice:

Rice weevil, *Sitophilus oryzae* Linn.
Rice moth, *Corcyra cephalonica* Staint.
Rust-red flour beetle, *Tribolium ferrugineum* Fabr.
Granary weevil, *Sitophilus granarius* Linn.

Vedder and Feliciano [59] found that when these insects infest unpolished rice they prefer to eat away the most nutritious part of the grain. This is the external layer or that portion removed during the polishing process. These insects thus convert an unpolished rice into a polished rice. Samples of unpolished rice which were infested with insects for one hundred days were analyzed before and after the period of infestation. The results showed a very decided decrease in the percentage of fat and phosphorus pentoxide. Unpolished rice, which before the infestation was beriberi-preventing, thus lost this medicinal property.

Heat for controlling insects in flour mills and grain elevators has been used considerably in the United States. Dean,[60] who investigated this problem, found that a temperature of only 118° to 125° F., (48° to 51.5° C.), maintained for several hours to enable the heat to penetrate all infested parts, will kill all insects and insect eggs. The heat, obtained from steam pipes, does not injure the grain and is more efficient than fumigation.

We found, as stated later, that insect infestation in rice bran may also be prevented by heat.

Decomposition of rice oil.—The deterioration of rice bran is not only caused by the ravages of insects but also by the decomposition of the fatty oil contained in the bran. Pure vegetable fats, or fatty oils, usually consist almost entirely of a mixture of glycerides of fatty acids. Rice oil, for instance, consists principally of the glycerides of oleic, linolic, and palmitic acids. Under certain conditions, such as the action of moisture and enzymes, these glycerides are gradually decomposed (hydrolyzed) and converted into glycerol and a mixture of free fatty

[58] Philip. Journ. Sci. 35 (1928) 382.
[59] Philip. Journ. Sci. 35 (1928) 383.
[60] Kansas Agr. Exp. Sta. Bull. 189 (1913).

acids. The free acids may then undergo oxidation and the fats acquire an unpleasant odor and taste, and become rancid. However, a high acid number is no indication of a rancid fat for rancid fats may contain either small or very large amounts of free fatty acids. According to Lewkowitsch [61] the initial phase of rancidity (hydrolysis) is accelerated by the action of enzymes. Fat-hydrolyzing enzymes occur in most, if not all, oleaginous seeds. The freshest vegetable oils and fats always contain at least minute quantities of free fatty acids. The formation of free fatty acids in vegetable oils is due to the action of moisture in the presence of enzymes (soluble ferments) which act as catalysts and accelerate the hydrolysis of the fats. Thus olein, $(C_{17}H_{33}COO)_3C_3H_5$, the fat which is the glyceride of oleic acid, when hydrolyzed yields glycerol, $C_3H_5(OH)_3$, and oleic acid, $C_{17}H_{33}COOH$.

$$(C_{17}H_{33}COO)_3C_3H_5 + 3HOH \rightarrow C_3H_5(OH)_3 + 3C_{17}H_{33}COOH.$$

For convenience it is usually customary to calculate the amount of the free fatty acids in vegetable oils simply as oleic acid.

At ordinary temperatures moisture alone is not effective in decomposing vegetable fatty oils (glycerides). According to Lewkowitsch: [62]

> At temperatures up to about 150° C., water does not attack glycerides but if the temperature be raised to 200° C., or more, the triglycerides are finally decomposed (hydrolyzed) into their proximate components, glycerol and fatty acids. . . . The hydrolysis thus produced at high temperatures is greatly accelerated if the action of the water is assisted by suitable chemical agents. If such agents are present, it is possible to reduce the temperature . . . the change may be brought about by water even at the ordinary temperature if naturally occurring ferments, such as lipase or steapsin, are intimately intermixed with the oils and fats.

Rice bran as it comes from the polisher has a fresh and somewhat sweet odor. If the bran is obtained from rice milled soon after the harvest the amount of free fatty acids in the fatty oil contained in the bran is usually very low. We found samples of bran that gave only 1.2 per cent of free fatty acids in the rice oil. Perhaps if the mill had been thoroughly cleaned before milling the grain the percentage of free fatty acids

[61] Chemical Technology and Analysis of Oils, Fats, and Waxes 1 (1921) 50, 52 and 54.

[62] Chemical Technology and Analysis of Oils, Fats, and Waxes 1 (1921) 49 and 50.

would have been even smaller. Samples of bran from grain which had been stored for some months gave a much higher percentage of free fatty acids in the rice oil ranging from about 2 to 6.5 per cent. From our results it would seem that, due to the action of moisture in the presence of enzymes, the fatty oil in the unhulled rice grain gradually decomposes to some extent when the grain is stored. Perhaps this is the reason that polished rice from freshly harvested grain has a better flavor than rice milled from grain that has been stored a long time. During the polishing process not all of the outer aleurone layer containing fats is removed from the rice kernel, for the polished rice still contains over 1 per cent of fat (Table 11). If the fats which remain with the polished rice are acid they may have a flavor which is not so agreeable as that of the pure glycerides (fats). Compared with other foods rice has relatively little flavor and so the presence of even a small amount of acid fat may, perhaps, affect very appreciably the flavor of polished rice.

The fatty oil in rice bran, fresh from the polisher, may contain only a very small percentage of free fatty acids but when the bran is allowed to stand there is a very rapid increase in the amount of free fatty acids contained in the fatty oil with a corresponding decrease in the amount of pure fat.

According to Browne [63] this rapid decomposition of rice oil is due to a fat-splitting enzyme (lipase). Excessive acidity has been observed in a few other vegetable oils, such as palm and olive, and has been found to be due to enzyme action.[64]

Concerning the production of palm oil in Africa Lewkowitsch[65] states:

> In consequence of the very crude mode of producing palm oil, causing it to remain for a considerable time in contact with fermentable vegetable tissue, hydrolysis rapidly sets in, so that the oil on reaching the coast contains already a notable amount of free fatty acids. Palm oil when shipped from the coast has at least 10–12 per cent of free fatty acids. The process of hydrolysis, once begun, continues in the barrels during the voyage, and in consequence thereof commercial palm oils, on arriving at their destination, contain frequently from 20 to 50 per cent, and even more, of

[63] Journ. Am. Chem. Soc. 25 (1903) 948.

[64] Lewkowitsch, J., Chemical Technology and Analysis of Oils, Fats, and Waxes 2 (1922) 363.

[65] Chemical Technology and Analysis of Oils, Fats, and Waxes 2 (1922) 558.

free fatty acids. In such palm oils free glycerol is found. In old samples the hydrolysis may even reach completion, so that such palm oil practically consists of free fatty acids. The progress of hydrolysis can be observed even in oils kept in glass bottles. Thus a sample of Drewin oil, which had originally the acid value 41.8, showed after six (summer) months the acid value 70.1.

In the case of rice oil we have a condition somewhat similar to that of commercial palm oil. Rice bran as it comes from the polisher contains fatty oil in contact with fermentable vegetable tissue. The rice oil in the bran contains free fatty acids showing that hydrolysis of the oil has already started before milling the grain. The longer the oil is allowed to remain in contact with the vegetable tissue the greater will be the production of free fatty acids unless something is done to stop the action of the enzyme and the decomposition of the oil.

Cattle frequently show a marked distaste for rice bran as a food. It has been found, in such cases, that the bran has a rancid taste. The oil in rancid bran usually has a high acid number indicating that the fats (glycerides) have decomposed and, to a considerable extent, have been converted into free fatty acids. Data showing the hydrolysis of rice oil, when the bran is allowed to stand for seven days, are given in Table 22.

TABLE 22.—*Hydrolysis of the fatty oil when rice bran is stored.*

	Sample.				
	1	2	3	4	5
Acid number of oil:					
From fresh bran	2.4	4.1	4.4	5.1	13.6
From bran stored seven days	17.0	24.8	30.7	34.2	58.9

The greater the amount of free fatty acids contained in the oil of fresh bran the greater the amount of hydrolysis.

We determined the daily hydrolysis of the fatty oil when rice bran is stored for twenty-one days. In the first sample of bran tested the acid number of the oil in the fresh bran was 4.88 and in the second sample it was 8.89. These samples of bran were taken fresh from the polisher, placed in bags of cheesecloth, and stored in a wire screen box. They were thus exposed to atmospheric moisture but protected from insects. The results are recorded in Tables 23 and 24.

TABLE 23.—*Daily hydrolysis of the fatty oil when fresh rice bran is stored.*

[Acid number of oil in fresh bran, 4.88.]

Number of days stored.	Acid number of oil in bran.	Free fatty acids (in oil) calculated as oleic acid.	Daily increase in free fatty acids (as oleic).	Actual amount of fat (as olein) hydrolyzed each day.	Purity of fat (as olein) in bran.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
0	4.88	2.45	----------	----------	97.44
1	10.28	5.17	2.72	2.84	94.60
2	15.49	7.79	2.62	2.73	91.87
3	20.08	10.09	2.30	2.40	89.47
4	23.77	11.95	1.86	1.94	87.53
5 [a]	----------	----------	1.44	1.50	86.03
6	29.50	14.83	1.44	1.50	84.53
7	32.93	16.55	1.72	1.79	82.74
8	35.66	17.92	1.37	1.43	81.31
9 [a]	----------	----------	1.25	1.30	80.01
10	40.52	20.43	1.25	1.30	78.71
11	43.49	21.86	1.43	1.49	77.22
12 [a]	----------	----------	1.01	1.05	76.17
13	47.50	23.88	1.01	1.05	75.12
14	49.98	25.12	1.24	1.29	73.83
15	51.54	25.90	0.78	0.81	73.02
16	53.93	27.10	1.20	1.25	71.77
17	54.98	27.64	0.54	0.56	71.21
18	57.61	28.96	1.32	1.37	69.84
19 [a]	----------	----------	1.15	1.20	68.64
20	62.19	31.26	1.15	1.20	67.44
21	64.24	32.29	1.03	1.07	66.26

[a] Acid value was not determined on this day. The results were calculated from data obtained the following day.

As shown by the data, when both samples of bran were stored, there was a great increase in the acid number of the oil and, of course, a corresponding increase in the amount of free fatty acids calculated as oleic acid. Since the free fatty acids are formed by a splitting of the fat, naturally the purity of the fat gradually decreased. Rice oil, which originally contained 95.33 per cent of fats (Table 24), was found to have only 49.39 per cent of fats after the bran had been stored for twenty-one days. During these three weeks of storage nearly half of the fats in the fatty oil was decomposed (hydrolyzed) and converted into glycerol and a mixture of free fatty acids.

For both samples of bran (Tables 23 and 24) the amount of free fatty acids in the oil more than doubled during the first day the bran was stored. After that the daily increase in free fatty acids and the actual amount of fat hydrolyzed each day

gradually decreased. That is, the rate of formation of free fatty acids in the oil decreased when the bran was stored. Lewkowitsch [66] states that, with castor oil, the more castor seed ferment present the greater the amount of hydrolysis. Increasing the amount of water also increases the hydrolysis. Free fatty acids, however, inhibit the action of the ferment. In our experiments we also found (Tables 23 and 24) that as the percentage of fatty acids increases the rate of hydrolysis decreases.

TABLE 24.—*Daily hydrolysis of the fatty oil when fresh rice bran is stored.*

[Acid number of oil in fresh bran, 8.89.]

Number of days stored.	Acid number of oil in bran.	Free fatty acids (in oil) calculated as oleic acid.	Daily increase in free fatty acids (as oleic).	Actual amount of fat (as olein) hydrolyzed each day.	Purity of fat (as olein) in bran.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
0	8.89	4.47	----------	----------	95.33
1	19.60	9.86	5.39	5.63	89.70
2	27.96	14.05	4.19	4.38	85.32
3 [a]	----------	----------	3.12	3.16	82.16
4	40.39	20.30	3.12	3.16	78.79
5	47.02	23.63	3.33	3.48	75.31
6	52.23	26.25	2.62	2.73	72.58
7	57.83	29.07	2.82	2.95	69.63
8	61.29	30.80	1.73	1.81	67.82
9	63.76	32.05	1.25	1.30	66.52
10 [a]	----------	----------	1.84	1.93	64.59
11	71.10	35.74	1.84	1.93	62.66
12	74.17	37.28	1.54	1.61	61.05
13	77.28	38.84	1.56	1.63	59.42
14	79.95	40.19	1.35	1.41	58.01
15	80.86	40.65	0.46	0.48	57.53
16	83.69	42.07	1.42	1.48	56.05
17 [a]	----------	----------	1.61	1.68	54.37
18	90.12	45.30	1.61	1.68	52.67
19	93.00	46.74	1.44	1.50	51.17
20	95.09	47.80	1.06	1.10	50.06
21	96.38	48.44	0.64	0.66	49.39

[a] Acid value was not determined on this day. The results were calculated from data obtained the following day.

PRESERVATION OF RICE BRAN

Preliminary heating experiments.—According to Browne [67] the activity of the fat-splitting enzyme contained in rice bran can be retarded very considerably by heating the bran to a

[66] Chemical Technology and Analysis of Oils, Fats, and Waxes 1 (1921) 94.

[67] Journ. Am. Chem. Soc. 25 (1903) 948.

temperature of 90° C. To prevent the formation of free fatty acids in rice oil and the resulting rancidity Browne suggested heating the bran, immediately after milling, to a dry heat sufficient to destroy the enzyme, such as is done in the kiln-drying of certain seeds.

We carried out a number of preliminary experiments to get an idea as to the temperature and length of time necessary to heat the bran in order to stop the enzyme action and prevent hydrolysis of the fatty oil contained in the bran.

In heating the bran we used an ordinary electric drying oven which was fitted with an automatic stirrer. The bran was placed in a large crystallizing dish and stirred continuously during the heating in order to keep it at a uniform temperature. Then it was placed in cheesecloth sacks and stored in a wire screen box. Results of these experiments are given in Table 25.

TABLE 25.—*Acid number of fatty oil after heating and storing rice bran in cloth sacks.*

Sample.	Acid number of oil in fresh bran (not heated).	Time of heating bran.		Acid number after storing bran—	
		Temperature 90°–95° C.	Temperature 98°–100° C.	Seven days.	Fourteen days.
		Hrs.	*Hrs.*		
6	4.8	----------	----------	32.9	49.9
7	8.8	----------	----------	57.8	79.9
8	7.2	2	----------	21.0	34.9
9	7.4	3	----------	19.1	32.8
10	7.5	4	----------	16.4	28.3
11 [a]	5.9	----------	2	16.1	----------
12 [a]	5.9	----------	3	15.8	----------
13 [a]	5.9	----------	4	13.4	----------
13–A	7.3	----------	5	15.5	----------
13–B	6.8	----------	6	12.7	----------

[a] These three samples were taken from the same lot of bran.

As shown by the data (Table 25) the acid number of the fatty oil in samples of bran (Nos. 6 and 7), which were not heated, increased considerably when the bran was stored. These data are included in the table merely for comparison. When the bran was heated the acidity of the fatty oil was much less than when the bran was not heated. Heating the bran did not stop the acidity of the oil from increasing but merely retarded the formation of free fatty acids. Moisture is removed by heating the bran and quite likely some of the enzymes are also destroyed.

With less moisture and enzymes present the hydrolysis of the oil is inhibited.

Increasing the time of heating and the temperature retards the rise in the acid number of the oil. Heating the bran at a temperature of 98° to 100° C., for six hours gave the best results in these preliminary experiments.

Wrappers for heated bran.—Even if heating the bran under the proper conditions prevents the formation of free fatty acids in the fatty oil contained in the bran, it is necessary to keep the heated bran in some kind of a closed container, otherwise the bran soon becomes infested with insects. We carried out another set of experiments by heating the bran at a temperature of 100° C., for three to six hours. The bran, after heating, was placed in paper bags, which were then wrapped in various kinds of paper or wrappers as a protection against such agencies as moisture and insects. The samples were stored in a wire screen box. In these experiments we wished to find a satisfactory and cheap container or wrapper for the bran. The results are recorded in Table 26.

As shown by the data (Table 26) the acidity of the fatty oil increases slightly during the heating of the bran. That is, the acid number of the oil after heating is slightly higher than before heating. This is due to the fact that the fat-splitting enzymes become more active with rise in temperature until the heat causes inactivity and finally destroys the enzymes.

As in the first experiments, heating the bran for six hours at a temperature of about 100° C., gave the best results (samples 14, 15, 20, 21, 22). Heating the bran for shorter periods of time gave a larger increase in the acid number of the fatty oil when the bran was stored.

Of the various materials in which we wrapped the paper packages of rice bran, after heating, we found that moisture-proof cellophane seemed to give the best results. The acid number of the fatty oil in sample 15 (Table 26) did not increase after storing the bran one month. The acid number in sample 14 scarcely increased even after storing the bran for two months. Cakes made from this bran after two months of storage were just as good as those made from fresh bran. Probably if this sample had not been opened for analysis, and thus exposed to moisture, we could have kept it much longer without any appreciable increase in acidity. However, storing it for another month, after opening the package, raised the acidity of the fatty oil to an acid number of only 8.1.

TABLE 26.—*Acid number of fatty oil after heating and storing rice bran in paper bags wrapped in different kinds of paper.*

Sample.	Acid number of oil in fresh bran.	Time of heating at 100°C.	Acid number of oil in bran.			Kind of paper used for wrapping bran sample after heating.
			After heating and before storing.	Months stored.		
				1	2	
		Hrs.				
13–C	8.6	4	8.8	10.1	----	Cellophane.
14	4.8	6	5.4	----	5.5	Do.
15	6.6	6	7.9	7.9	----	Do.
16	4.9	3	6.3	16.2	43.4	Heavy wax paper.
17	6.6	4	7.3	15.1	44.7	Do.
17–A	6.6	4	7.3	----	37.0	Do.
18	8.9	5	11.5	16.9	43.3	Do.
18–A	8.9	5	11.5	----	36.7	Do.
19	8.1	5	9.0	11.0	26.9	Do.
20	6.2	6	7.5	8.5	22.6	Do.
20–A	6.2	6	7.5	----	19.9	Do.
21	7.4	6	9.2	10.3	20.9	Do.
21–A	7.4	6	9.2	----	17.8	Do.
22	4.0	6	4.8	5.4	11.1	Do.
23	7.4	3	8.2	26.9	----	Coarse wax paper.
24	6.4	4	7.0	24.6	----	Do.
25	5.3	5	6.1	11.8	----	Do.
26	6.9	5	8.1	20.0	----	Do.
27	9.2	6	9.9	15.7	----	Do.
28	8.5	6	9.2	13.4	----	Do.
29	8.4	----	8.4	96.3	----	Green paper.
30	8.4	4	8.7	44.7	----	Do.
33	6.6	----	6.6	109.6	----	Black paper.

If the bran can be kept a month with very little change in acidity of the fatty oil, quite likely it could be stored very much longer without any very appreciable deterioration.

We obtained fairly good results with a heavy wax paper. As shown by the data for samples 20, 21, and 22 there was only a very small increase in acidity when the heated bran was stored one month. Storing the bran for a second month gave a considerable increase in the acid number of the fatty oil. Evidently the wax paper is much inferior to cellophane for preserving the bran. However, after storing the heated bran for two months, those samples with a high acid number did not show any signs of rancidity.

When a coarse wax paper was used for storing the bran our results were not so good (samples 23 to 28). When the paper was folded the waxed surface cracked thus admitting atmospheric moisture.

We also used colored papers (green and black). The bran was placed in a paper bag which was then wrapped in several thicknesses of the colored paper.

Coe and Le Clerk [68] studied the keeping qualities of oil-bearing foods wrapped in colored papers. Concerning rice bran they state:

> Rice bran and polish were wrapped in various colored cellophane and exposed to direct sunlight. This experiment resulted in the discovery which is the subject of this paper, viz., that certain wave lengths of light promote rancidity, while certain others exert a protective action against this change. – – – – The use of a black wrapper or one of the proper shade of green will protect the food product for a sufficiently long time to permit of its sale and consumption before spoilage by rancidity develops.

Our results showed that these colored wrapping papers (samples 29, 30, and 33) are not very effective in retarding the hydrolysis of rice oil. When fresh bran (not heated) was stored one month in paper packages wrapped in these colored papers the acid number of the rice oil increased from about 8 to more than 90. These colored papers retarded the rancidity of the bran for, when tested by the kreis method, these samples showed only incipient rancidity. Heating the bran four hours retarded hydrolysis but the acid number after storing one month was considerably higher for the colored paper than for the heavy wax paper (sample 17).

The results of this second set of heating experiments indicate that a method, which may be used for preserving rice bran, is to take bran fresh from the mill polisher and heat it at a temperature of 100° C., for six hours. This treatment removes all the moisture and checks the action of enzymes. If the bran, after heating, is packed in moisture-proof containers it may be kept for several months in a fresh condition. As explained later, subsequent experiments showed that by heating the bran at a temperature somewhat above 100° C., the time required for heating the bran can be reduced considerably.

[68] Cereal Chemistry 9 (1932) 519.

Since a double wrapping of moisture-proof cellophane preserved the bran better than any other wrapper we used it would seem that preservation of the bran, after heating, depends principally on excluding moisture and insects.

Enzymes in rice bran.—The fact that we had to heat rice bran at a temperature of 100° C., for six hours to check the action of the fat-splitting enzymes would seem to indicate that the enzymes in rice bran, like certain enzymes from other sources, have a considerable tolerance for heat.

Lewkowitsch [69] cites an observation made by Nicloux concerning castor seed "cytoplasma." This is the colloidal matter which occurs in the cells of the seed and naturally contains castor-seed enzymes. This castor seed "cytoplasma," which, under suitable conditions, causes rapid hydrolysis of oils and fats, if suspended in oil, may be heated for twenty hours at a temperature of 100° C., without losing its fat-hydrolyzing power.

According to Williams[70]—

> The temperature at which enzymes are rapidly destroyed varies with the particular enzyme and also with the conditions. For many enzymes 70°–80° brings about rapid destruction but some enzymes of bacterial origin are able to withstand 100° for a short time in an aqueous medium. If enzyme preparations are dried and heated in the dry condition they are able to withstand much higher temperatures. This is somewhat in line with the fact that we have already noted that enzymes are colloidal in nature and their destruction is due to the destruction of the colloidal condition. When dry, enzymes are not in the colloidal state and apparently are unaffected by conditions that will destroy them while in the colloidal condition.
>
> Enzyme preparations which have undergone much purification are more readily destroyed than cruder preparations. The impurities apparently afford protection of some sort; some impurities no doubt act as protective colloids. The presence of the substrate in some cases protects an enzyme against destruction by heat.
>
> Interesting cases of reactivation of enzymes which should throw light on their character have been reported. Amylase from Aspergillus oryzae [rice mold], which has been destroyed [rendered inactive] by heating to 95°, regains its activity by standing several days. Similar results have been obtained with a few other enzymes. This result lends support, perhaps, to the idea that enzymes are actually the colloidal substances themselves rather than active catalysts on colloidal "carriers."

From our experiments it would appear that heating rice bran, at a temperature of 100° C., for six hours, does not really de-

[69] Chemical Technology and Analysis of Oils, Fats, and Waxes 1 (1921) 53.

[70] Introduction to Biochemistry (1931) 236.

stroy the enzymes but merely renders them dormant. As shown by the data (Table 27) when fresh rice bran was heated under the proper conditions and stored in a moisture-proof package there was no appreciable increase in the acidity of the fatty oil contained in the bran (samples 14 and 15). When the heated bran was allowed to absorb moisture the acidity of the fatty oil increased (samples 27 and 13–B). However, this increase in acidity was not nearly so great as when the bran was not heated (sample 6).

TABLE 27.—*Effect of moisture on stored rice bran.*

Sample.	Time of heating at 100° C.	Time stored.		Acid number of oil in bran.		Wrapper used.
				Before storing.	After storing.	
	Hrs.	*Days.*	*mos.*			
14	6	0	2	5.4	5.5	Moisture-proof cellophane.
15	6	0	1	7.9	7.9	Do.
27	6	0	1	9.9	15.7	Coarse wax paper not quite moisture proof.
13–B	6	7	0	6.8	12.7	Cloth sack, not moisture proof.
6	----------	7	0	4.8	32.9	Sample (not heated) stored in cloth sack not moisture proof.

When rice bran is heated sufficiently moisture is removed and the enzymes in dry condition apparently lose their active colloidal character. Under favorable conditions, such as absorption of moisture, the enzymes gradually regain their colloidal character and again become active as indicated by the increase in the acidity of the fatty oil.

Testing fat-splitting enzyme activity.—We carried out some experiments to ascertain the keeping properties of rice bran heated above 100° C. We heated the bran, with constant stirring, at 120° C., for six hours. To test the enzyme activity and resulting hydrolysis of the rice oil in the bran, the hot bran was quickly placed in a sterilized glass bottle and sterilized cotton was inserted in the top of the bottle. Paper laid over the cotton served to keep out dust. Under these conditions the bran could absorb moisture through the cotton stopper.

If the enzymes are destroyed by heating the bran at the higher temperature then the acidity of the fatty oil should not increase when the bran absorbs moisture under these conditions; for, in the absence of enzymes or other catalysts, moisture is not effective in hydrolyzing vegetable oils at ordinary temperatures.

For comparison we stored in sterilized bottles and under the same conditions two other samples of bran. One was a sample of fresh bran which was not heated and the other was a sample heated at 100° C., for six hours. The results of storing these three samples for thirty-one days are recorded in Table 28.

TABLE 28.—*Testing the activity of fat-splitting enzymes in rice bran.*

[The bran was stored for thirty-one days in sterilized bottles with sterilized cotton as stoppers.]

Sample.	Time of heating.		Moisture.		Acid number of oil in bran.	
	100° C.	120° C.	Before storing.	After storing.	Before storing.	After storing.
	Hrs.	*Hrs.*	*Per cent.*	*Per cent.*		
34 [a]			14.3	19.6	4.4	143.8
35 [b]	6			5.4	5.8	22.1
36 [b]		6		5.2	6.8	8.0

[a] The fresh bran, which was not heated, became moldy during storage.
[b] Sample was moisture free before storing.

The bran (sample 34) that was not heated had a high moisture content and on this account became moldy during storage and the fatty oil in it hydrolyzed to an unusual extent as indicated by the high acid number (143.8).

Both samples of the heated bran had a pleasant, sweet odor and were in very fresh condition after they were stored for thirty-one days.

The bran which was heated at a temperature of 100° C., (sample 35) absorbed 5.4 per cent moisture. Heating the bran at this temperature did not destroy the enzymes but merely rendered them inactive, for with absorption of moisture the enzymes again became active and the acid number of the fatty oil in the bran increased from 5.8 to 22.1.

Bran heated at a temperature of 120° C., (sample 36) absorbed 5.2 per cent moisture, but the acidity of the fatty oil increased only very slightly. From these results it would seem that by heating the bran at the higher temperature nearly all the enzymes are destroyed, as the fatty oil is only very slightly hydrolyzed when the bran absorbs moisture during storage. Quite likely the very few enzymes that remain are not active enough to cause any serious deterioration when the bran is stored for a much longer period of time.

Rice bran heated at about 100° C., for six hours and stored in a moisture-proof container apparently has excellent keeping

properties (Table 27). However when the bran is stored, in a sterilized bottle where moisture can enter, there is quite an increase in the acidity of the fatty oil in the bran (Table 28). It would seem that bran thus heated, really does not have such good keeping properties and only keeps well under special conditions. Storing the bran properly with access to moisture and subsequently determining the acidity of the rice oil, seems to be a good method for testing the keeping properties of the bran. It affords a reliable means of ascertaining the results of enzyme activity under favorable conditions.

Temperature and time of heating rice bran.—In preparing rice bran which will keep in storage commercially the shorter the time necessary to heat it the better, for it makes the process less expensive and more convenient to carry out. The results of our experiments on heating the bran and storing it in sterilized bottles indicate that the most appropriate temperature for heating is between 100° and 120° C., and the time is six hours or less. In order to ascertain more exactly the best heating conditions we carried out another set of experiments by heating the bran at various temperatures between these limits and for different intervals of time. As in the previous experiments the bran was again stored, with access to moisture, in sterilized bottles. The results are recorded in Table 29.

TABLE 29.—*Temperature and time of heating rice bran to prevent deterioration in storage.*

[The bran, after heating, was stored for thirty-one days in sterilized bottles with sterilized cotton as stoppers.]

Sample.	Time of heating.			Moisture after storing.	Acid number of oil in bran.	
	105° C.	110° C.	115° C.		Before storing.	After storing.
	Hrs.	*Hrs.*	*Hrs.*	*Per cent.*		
37	3			5.77	4.56	18.88
38	4			5.76	5.12	16.86
39		3		6.22	5.28	17.52
40		4		6.12	5.63	15.49
41			3	6.87	4.67	16.65
42			4	5.60	5.59	12.06

NOTE.—The samples of bran were moisture free before storing.

As shown by the data (Table 29) when rice bran is heated below 120° C., and stored there is a decided increase in the acidity of the fatty oil contained in the bran. This shows that the

enzymes are not all destroyed at temperatures between 100° C., and 120° C. Since rice bran heated above 105° C., acquires a rather dark color, which is not desirable, it would seem that heating the bran at 105° C., for three hours affords heating conditions about as appropriate as any. Heating the bran under these conditions and storing it in moisture-proof containers would serve to keep the bran in good condition for a considerable length of time.

Heating the bran removes moisture and stops the destructive action of enzymes, as most of them are destroyed. This prevents decomposition and subsequent rancidity of the fatty oil contained in the bran. The heating does not affect the vitamins but destroys any mold spores, insects, or insect eggs which may be in the bran. When stored in moisture-proof containers, the heated bran does not become rancid, moldy, or infested with insects.

Bacteria in rice bran.—If the fatty oil in rice bran has the general properties of other vegetable fatty oils then the decomposition (hydrolysis) of rice oil in rice bran is due to moisture in the presence of fat-splitting enzymes contained in the tissues of the bran. The question might be raised that, possibly, bacteria as well as enzymes may, perhaps, be active in decomposing the fatty oil in rice bran. In order to settle this question we heated rice bran at a temperature of 120° C., for six hours. During the heating the bran was stirred continually. The heating destroyed the bacteria and also any mold spores or insect eggs that may have been in the bran. A portion of the hot bran was quickly placed in a sterilized bottle which was stoppered with sterilized cotton. Another portion of the heated bran was placed in an open vessel and thus exposed to bacteria in the air. This bran was stirred occasionally and allowed to stand in the air for four hours. It was then placed in a sterilized bottle which was stoppered with sterilized cotton. These two samples were covered with paper to keep out dust and allowed to stand in the air, under identical conditions, and absorb moisture through the cotton stoppers for 31 days.

The first sample quite likely contained only a very few bacteria while the second, which was allowed to stand in the air, certainly had considerably more than the first. For comparison we simply designated the first sample as "without bacteria" and the second as "with bacteria." The results of these experiments are recorded in Table 30.

TABLE 30.—*Effect of bacteria on the decomposition of rice oil in rice bran.*

[The bran was heated at 120° C.. for six hours and stored for thirty-one days, exposed to moisture, in sterilized bottles.]

Rice bran.	Moisture.		Acid number of oil in bran.	
	Before storing.	After storing.	Before storing.	After storing.
Without bacteria [a]		4.50	4.60	6.18
With bacteria [b]		4.73	[c] 4.60	6.45

[a] The bran, heated for six hours at 120° C., was placed immediately in a sterilized bottle which was stoppered with sterilized cotton.

[b] The bran, heated as above, was placed in an open vessel and exposed to the air, with occasional stirring, for four hours. The bran was then placed in a sterilized bottle which was stoppered with sterilized cotton.

[c] The acid number was determined after heating the bran and not after exposing it to the air for four hours.

If bacteria are active in hydrolyzing rice oil then, after storage, the rice oil in the bran with bacteria should have a much higher acid number than the rice oil in the bran without bacteria. As shown by the data (Table 30) both samples gave about the same results so evidently the decomposition of rice oil in rice bran is not due to bacteria.

The acid number of the rice oil in both samples of bran increased slightly during storage. This would seem to indicate that the enzymes in rice bran are not totally destroyed even after the bran is heated at a temperature of 120° C., for six hours. Apparently a very few still remain somewhat active.

The rice oil in the bran with bacteria gave a slightly greater increase in acidity, during storage, than the oil in the bran without bacteria. This was probably due to the fact that the bran with bacteria was stirred in the air for four hours before bottling and absorbed more moisture than the bran without bacteria. Both samples of bran were moisture free immediately after heating.

Sieving rice bran before heating.—Commercial rice bran usually contains some fragments of rice kernels or polished rice. It may also have some broken rice hulls or other foreign matter if the bran has not been milled properly. If the bran is to be used for making bakery products or other foods, it should be sieved as it is not desirable to have hard particles in the bran and moreover rice hulls are considered to be injurious for human consumption. In sieving the bran the hard particles are retained

by the sieve. The question naturally arises as to how much of the nutritious constituents are removed from the bran by sieving it. We obtained two samples of fresh rice bran (200 grams each) and, by analysis, found the oil content of one to be 21.88 per cent (calculated on a moisture-free basis) and the other to be 23.51 per cent. This showed that these samples of bran were not purposely adulterated with rice hulls. These samples were sieved through a large, 30-mesh, inclined sieve. Dr. A. J. Hermano tested the fine bran which passed through the sieve and also the coarse material retained by the sieve for the fat-soluble vitamin A and the water-soluble vitamin B_1. Both the fine bran and the coarse material gave positive tests for these vitamins (Table 31).

The coarse material consists largely of fragments broken off from the surface of the rice kernel. These fragments contain a considerable portion of the aleurone layer of the rice kernel and therefore they contain rice oil, fat-soluble vitamins and also the water-soluble vitamin B_1.

TABLE 31.—*Rice oil and vitamins (A and B_1) in sieved bran.*

Sample.	Bran retained by 30-mesh sieve.			Bran passing through 30-mesh sieve.		
	Amount.	Vitamins (A and B_1).	Oil content of bran.	Amount.	Vitamins (A and B_1).	Oil content of bran.
	Per cent.		*Per cent.*	*Per cent.*		*Per cent.*
1	13.00	Positive	24.81	87.00	Positive	21.59
2	15.50	do	24.25	8 .50	do	23.19
Average	14.25		24.53	85.75		22.39

As shown by the data an average of 14.25 per cent of coarse material was removed from the bran by sieving it. This is about 1 per cent less than the average of the results recorded in Table 3. Since this coarse material contained 24.53 per cent fatty oil then the amount of fatty oil removed from the bran by sieving was about 3.5 per cent ($14.25 \times 0.2453 = 3.49$). The coarse material removed by sieving is very suitable for feeding chickens or for other purposes.

In sieving rice bran through a large, 30-mesh, inclined screen the bran does not sieve by mechanically shaking the screen because there are no oval solid particles, like rice grains, to roll down the screen. However, if the bran is spread over the screen in a thin layer and the screen is tapped frequently with a rod, so that the screen vibrates perpendicularly, then the fine bran

will pass quickly through the screen while the coarse material is retained. The coarse material is then removed and a new portion of bran spread over the screen.

Rice-bran cooker.—The Bureau of Science has recently installed a rice-bran cooker (Plate 10). This cooker is a drum-shaped apparatus which has an internal diameter of 100 centimeters and an internal height of 40 centimeters. The side and bottom are surrounded by a jacket through which steam may be admitted when the cooker is in operation. In the interior of the cooker and very near the bottom there is a stirrer with four iron paddles that serve to stir the bran when it is heated. Layers of asbestos wrapped around the outside of the cooker prevent loss of heat. This cooker heats the bran satisfactorily, in fact, the bran may be heated easily to a temperature of 125° C.

Our method for preparing rice bran so that it will keep in storage is as follows: Bran fresh from the polisher is sieved through a large, 30-mesh screen by tapping the screen so that it will vibrate perpendicularly. The coarse material, which does not pass through the screen, may be discarded and used for feeding chickens. If it does not contain rice hulls or other foreign matter it may be ground finely and returned to the bran. The sieved bran is then placed in the cooker and heated, with continual stirring, for three hours at a temperature of about 105° C. Stirring the bran facilitates the removal of moisture. The bran while still hot is then packed in moisture-proof containers or packages. When prepared in this manner it will keep in a fresh condition for a considerable length of time.

Although the heated bran is slightly darker in color than the fresh, raw bran it has a pleasanter and sweeter odor and flavor than the raw bran.

Heating bran in outlying districts.—In outlying districts it is often not feasible to procure bran which has been properly heated in a cooker and stored in moisture-proof containers. Bran which will keep in storage for a short time may be prepared in a rather crude manner at home. This is done by simply heating fresh bran in a frying pan over a low fire. The bran should be stirred continually and heated about an hour or so until it turns slightly darker than the fresh bran. Care should be taken not to burn the bran. After it is heated the bran should be placed in a can or glass jar and this closed tightly to prevent entrance of moisture. This crude method removes nearly all of the moisture from the bran and by storing it in

containers which are fairly air-tight the bran will keep in good condition for a week or more.

Rice bran is at present a very cheap substance and contains fats, proteins, and vitamins that are the most nutritious constituents of the rice grain. Excellent bakery products and other foods may be made from rice bran. When it is not convenient to procure fresh bran the heated bran, preserved in proper containers, may be used. It is preferable to use the heated bran because it keeps better than raw bran.

SUMMARY

Rice cultivation.—There are many varieties of rice grown in the Philippines. These different varieties are distinguished by their physical characteristics and recorded under permanent numbers in the Philippine Bureau of Plant Industry. During the years 1921 to 1930 the average yearly production of paddy rice was more than two million metric tons.

Rice straw.—Rice straw, obtained as a by-product in threshing rice, is used for various purposes. It is especially suitable for cultivating mushrooms and for making tissue paper.

Philippine process of milling rice.—In the Philippine process of milling the paddy rice is passed through a rice huller which breaks the hulls. The mixture of broken hulls, unpolished (hulled) rice, and paddy rice (not broken) is sieved to remove fine particles and then carried to the blower. This removes the hulls which are usually taken to the boiler to be used as fuel. The mixture of unpolished rice and paddy rice is next taken to the separator, which removes the paddy rice from the unpolished rice. The paddy rice is returned to the rice huller while the unpolished rice goes through the polisher. In the polishing process rice bran is removed from the rice kernel (unpolished rice) to produce white polished rice. The bran consists of the outer layer of the rice kernel together with the rice grain embryo.

Philippine rice-mill products consist principally of polished rice, hulls, bran, and small broken grain; also unpolished rice, when desired.

Samples of rice-mill products were collected from 14 Philippine mills. The data on these products, arranged in tabular form, afford a convenient means for checking up the efficiency of the principal rice-mill machinery—the rice huller, blower, separator, and polisher.

The Philippine process of milling rice is quite different from that used in the United States. In the Philippines the scraping and polishing of the grain are done in one machine—the rice polisher. In the United States these two operations are performed in separate machines. In Philippine mills the grain is broken in both the rice huller and polisher.

We compared the amount of whole and broken polished rice grains obtained during the milling of rice in Philippine and American mills. The results showed that the percentage of whole grains produced in Philippine mills, which have only one polisher, compares very favorably with the best results obtained in American mills.

Rice starch.—Although rice starch is not strictly a rice-mill product it has been mentioned, since it is an important commercial product made from polished rice. Compared to other starchy materials rice contains a relatively high percentage of starch. Rice starch is used commercially for various purposes such as laundering, preparing foods, making paste and medicinal tablets. It is also employed extensively in the cosmetic industry for making face powders, because the particles of starch are much finer than those of any other cereal and adhere excellently to the skin.

Rice hulls.—Rice hulls are used for various purposes such as fuel, packing hygroscopic materials, filtering, and percolating. They are also employed in making an edible rice cellulose. They consist largely of crude fiber and also have a rather high ash content. On account of their very high silica content the ashes of rice hulls, when finely powdered, serve as a good polishing powder. They may also be useful for making polishing pastes and scouring soaps.

Polished and unpolished rice.—After the paddy (unhulled) rice is passed through the rice huller to remove the hulls the unpolished (hulled) rice then goes through the polisher. There are several reasons for polishing rice. Polished rice is clean, white, and tasty in appearance whereas the unpolished rice is slightly colored and not so inviting. Polished rice has much better keeping qualities than unpolished rice. The unpolished rice loses its flavor in a tropical climate because the fats in it become rancid. Again the unpolished rice has a tendency to get moldy and become infested with weevils and other insects which destroy the outer mealy layer of the grain. Polished rice differs from unpolished rice in that the unpolished rice contains

the nutritious constituents (fats, proteins, and vitamins) of the rice grain. Polished rice contains proteins but very little of the fats and vitamins.

Beriberi is a disease contracted by people who live on a diet composed principally of polished rice. When unpolished rice is used as a diet this disease is not contracted because the unpolished rice contains vitamin B_1 which prevents beriberi.

Nutritious parts of the rice grain.—Fats, proteins, and vitamins, the most nutritious constituents of the rice grain, are contained chiefly in the embryo and aleurone layer of the unpolished rice. The aleurone layer is the part of the rice kernel that lies just beneath the seed coat.

During the polishing process the entire seed coat of the unpolished rice is removed. The embryo (germ) is also removed as well as most of the aleurone layer of cells. Polished rice usually contains small portions (remnants) of the oily aleurone layer. The fatty oil contained in these portions of the aleurone layer becomes rancid when the polished rice is stored for some time and as a consequence the polished rice tends to lose its fresh flavor.

Rice bran.—That portion of the rice kernel removed during the polishing process is called rice bran. The rice bran is also known locally as darak, tikitiki or rice polishings. The bran contains the seed coat and germ of the unpolished rice (rice kernel). The bran also contains a considerable portion of the aleurone layer of the unpolished rice as well as some starchy material beneath the aleurone layer.

Most of the nutritious constituents of the rice grain (fats, proteins, and vitamins) are contained in the rice bran. High-grade bran, which is moisture free, should contain at least 20 per cent of vegetable fatty oil.

Rice bran suitable for human consumption should contain practically no rice hulls as it is generally believed that the hulls have an irritating effect upon the stomach and intestines. The presence of hulls in the bran may be determined by observing the bran under the microscope. In milling rice bran intended for edible purposes the mill should have a very efficient blower which will remove practically all the rice hulls from the unpolished rice. If the grain before polishing contains no hulls then the bran removed from the grain during the polishing process will also be free of hulls unless it is purposely mixed with them.

Rice-bran oil (rice oil).—Rice bran, which is moisture free, contains at least 20 per cent of fatty oil (rice oil). The oil consists principally of the glycerides of oleic, linolic, and palmitic acids. It is difficult to obtain the fatty oil from rice bran by pressure unless a high pressure (about 8,000 pounds) is used. However, the oil may be extracted by solvents such as ether and hot coconut oil.

Vitamins in rice bran.—Rice bran contains the water-soluble vitamin B_1 which prevents beriberi. The rice oil (fats) in rice bran contains the fat-soluble vitamins A and E. Vitamin A prevents eye afflictions and E sterility. Vitamin D, which prevents rickets, is developed in irradiated rice oil.

Tikitiki extract, made in the Bureau of Science, is an extract of rice bran containing vitamin B_1. It is used as medicine for curing beriberi.

The yield of tikitiki extract from rice bran varies considerably depending upon the quality of bran used in making the extract. During the year 1932 the average monthly production in the Bureau of Science was 69 bottles (50 cubic centimeters each) of extract for 1 sack (50 kilos) of bran. The potency of 1 cubic centimeter of this standard extract is about equivalent to that of 14.5 grams of high-grade rice bran.

Tests made for standardizing this extract showed that when 0.2 cubic centimeter of the extract is added daily to a basal ration deficient in vitamin B_1 the ration then contains sufficient vitamin B_1 to support a growing rat. Pigeons which had contracted polyneuritis were cured in one day when given an aqueous solution containing 0.0175 gram of the extract. The same results were obtained with 10 milligrams of activated clay which is equivalent to one unit of vitamin B_1. This activated clay serves as an international standard for vitamin B_1.

In the United States the use of vegetable oils, particularly coconut oil, in making margarine has increased very considerably in recent years. Coconut oil does not contain fat-soluble vitamins. Since rice oil contains the fat-soluble vitamins A and E it might serve as an important product for use in the margarine industry as the rice oil would supply the vitamins which are not contained in the coconut oil. Mixtures of coconut and rice oils should make a margarine more like natural butter than when coconut oil alone is used.

Rice oil is very much darker in color than coconut oil. Color tests on mixtures of rice and coconut oils show that, as the

percentage of rice oil in the mixture increases, there is a much greater increase in the yellow hue than in the red.

Proteins and mineral constituents.—The proteins in rice bran appear to be comparable to soy-bean protein, which is similar to both meat and milk proteins. In their general amino-acid make-up the rice-bran proteins have a high biological value comparing favorably with meat proteins. The protein nitrogen content of rice bran is about 8 times the nonprotein nitrogen.

Rice bran contains a relatively large amount of phosphorus as compared to lime. These mineral constituents are unbalanced and so in this respect the nutritive value is deficient. For people who live on a diet containing rice bran, these mineral constituents may be balanced to a considerable extent by eating vegetables that have a high lime content.

Nutritive value of rice bran.—Rice bran is the most nutritious part of the rice, since it contains fats, proteins, and vitamins. It has excellent food constituents with a high calorific value and is more nutritious than hydraulic copra cake, wheat bran, Graham and straight grade flour. Rice bran not only serves as an excellent material for cattle food but it is also very suitable for human consumption. For people who do not care for the natural flavor of rice bran this may be toned down considerably by diluting the bran with wheat flour. A mixture consisting of 3 parts of wheat flour and 1 part of rice bran makes a good combination for bakery products such as bread and cakes. Rice bran does not contain gluten and so, when used alone, it does not make bread that will rise. The addition of wheat flour not only weakens the flavor of the bran but also supplies the gluten necessary for making bread. The bran flavor may be entirely neutralized or disguised by making the bakery products with other characteristic flavors, such as ginger, cinnamon, or chocolate.

In the Philippines beriberi is a very common and fatal disease among the poorer classes who live on a diet that consists principally of polished rice and is deficient in vitamin B_1. It has been estimated that for people who are susceptible to beriberi a small amount of rice bran (30 grams) contains about enough of the antineuritic vitamin B_1 for their daily requirements. This is about equivalent to 11 level (not heaping) teaspoonfuls of bran or approximately 2 cubic centimeters of standard rice-bran (tikitiki) extract. The annual production of rice bran in the Philippines is about sufficient for all the people who need

the bran for its medicinal value and also for others who might benefit by using it.

Deterioration of rice bran.—Deterioration of rice bran is caused by insect infestation and also by the decomposition of rice oil. Rice bran contains a fatty oil (rice oil) in contact with fermentable vegetable tissue. When the fresh bran is stored the fats in the oil are decomposed (hydrolyzed) and converted into a mixture of free fatty acids and glycerol. This decomposition of the fats in rice oil is due to the action of moisture in the presence of vegetable tissue which contains fat-splitting enzymes. When this decomposition has proceeded to any considerable extent the rice oil usually becomes rancid and the bran acquires a disagreeable taste. A sample of fresh rice bran which originally contained 95.33 per cent of fats in the fatty oil, was found to have only 49.39 per cent of fats in the oil after storing the bran, with access to moisture, for twenty-one days. The greater the amount of free fatty acids contained in the fatty oil of fresh bran the greater the amount of hydrolysis when the bran is stored. However, the rate of formation of free fatty acids in the oil decreases on storing the bran.

Preservation of rice bran.—Our results indicate that the most convenient method for preserving rice bran is to heat the bran at a temperature of about 105° C., for three hours and then keep it in moisture-proof packages. Heating the bran removes moisture, stops the destructive action of the enzymes, destroys any mold spores, insects, or insect eggs which may be contained in the bran but does not affect the vitamins. The preservation of the bran, after heating, seems to depend principally on excluding moisture and insects. This may be accomplished satisfactorily by packing the bran in moisture-proof containers or wrappers. Bran, thus prepared, keeps well and does not become moldy, rancid, or infested with insects.

Of the various materials which we used to wrap the paper packages of rice bran, after heating, we found that moisture proof cellophane gave the best results. Tightly closed cans would very likely serve excellently for keeping the bran but such containers would be too expensive for the poorer classes.

The enzymes in rice bran have a considerable tolerance for heat. Heating the bran at a temperature of 100° C., for six hours, does not seem to destroy the enzymes but merely renders them dormant. When the bran is heated sufficiently moisture is removed and the enzymes in dry condition apparently lose

their active colloidal character. Under favorable conditions, such as absorption of moisture, the enzymes gradually regain their colloidal character and again become active as indicated by increased acidity of the fatty oil in the bran.

Fresh bran heated at a temperature of 120° C., for six hours and stored, with access to moisture, for thirty-one days absorbed 5.2 per cent of moisture but the acidity of the fatty oil in the bran increased only very slightly. This would seem to indicate that nearly all the enzymes are destroyed at the higher temperature.

The activity of fat-splitting enzymes in rice bran, which has been heated, may be tested by storing the bran with access to moisture in a sterilized bottle and subsequently determining the acidity of the rice oil in the bran. This method affords a reliable means of ascertaining the results of enzyme activity under favorable conditions.

Tests carried out to ascertain if bacteria as well as enzymes are active in decomposing the fatty oil in rice bran showed that the decomposition of rice oil is not due to bacteria.

Commercial rice bran may contain some fragments of rice kernels and rice hulls. If the bran is to be used for making bakery products or other foods it is advisable to sieve it to remove the hard particles. In sieving the bran through a 30-mesh screen about 3.5 per cent of fatty oil is removed with the coarse material.

In preparing rice bran for storage it is advisable to use a specially constructed cooker containing a stirrer. Stirring the bran while heating facilitates the removal of moisture. The bran while still hot should be packed in moisture-proof containers.

In outlying districts where proper cooking facilities are not available the bran may be heated, with continual stirring, in a frying pan over a low fire. The heating should be continued until the bran turns slightly darker in color. After it is heated, the bran should be placed in a can or glass jar which may be closed tightly to prevent the entrance of moisture. The bran will thus keep in good condition for a week or more.

Although the heated bran is slightly darker in color than the fresh, raw bran it has a pleasanter and sweeter odor and flavor.

Résumé.—As a rice-mill by-product more than 111,000 tons of fine rice bran are produced annually in the Philippines. At

present this material is very cheap and is used for feeding cattle and poultry. Rice bran contains fats, proteins, and vitamins, which are the most nutritious constituents of the rice grain. It would seem that rice bran has the characteristics of a very good food.

The reason that rice bran has not become a popular human food is probably due to the fact that it contains a quantity of vegetable fatty oil. When the bran is stored the oil becomes rancid and the bran acquires a disagreeable taste. In order to make the bran suitable for human consumption it is only necessary to separate the coarse material and to heat the fresh bran properly in order to remove all the moisture and stop the destructive action of the fat-splitting enzymes. The hot bran should then be stored in moisture-proof packages.

Excellent bakery products and other foods may be made from bran which has been properly heated and packed. On account of its nutritious constituents rice bran should serve as an important material for Philippine foods. For the poorer classes who live on a diet composed principally of polished rice and is more or less deficient in fats, proteins, and vitamins, the use of rice bran as a food would serve to supply, to a considerable extent, the present dietary deficiency. It would not only prevent sickness and death from beriberi but the health of the people would be generally improved. Moreover by utilizing this domestic by-product of the rice mills the Filipinos would be developing the natural resources of their own country, and the importation of rice and other foodstuffs from foreign countries would be greatly diminished.

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ILLUSTRATIONS

PLATE 1

FIG. 1. Rice field, Philippine Islands.
2. Rice panicles.
3. A single rice panicle.

PLATE 2

FIG. 1. Rice stacks ready for threshing.
2. Philippine rice mill.

PLATE 3. PHILIPPINE RICE MILL, INTERIOR VIEW

FIG. 1. Rice huller.
2. Blower.
3. Separator.
4. Polisher.

PLATE 4

FIG. 1. Rice huller opened and showing the grinding stones.
2. Rice huller, closed.

PLATE 5. RICE POLISHER

FIG. 1. Polishing stone.
2. Wire screen (part removed to show abrasive stone).
3. Outside view of rubber strip (polisher), showing adjustment screws.

PLATE 6. RICE GRAINS

FIGS. 1 and 4. Paddy (unhulled) rice.
2 and 5. Unpolished rice.
3 and 6. Polished rice.

PLATE 7

FIG. 1. Longitudinal section of paddy rice grain (Malagkit variety).
h, hull.
sc, seed coat.
al, aleurone layer of cells.
en, endosperm with starch cells.
c, cotyl.
p, plumule.
r, radicle.
em, whole embryo (comprising cotyl, plumule, and radicle).
2. Segment of a part (cotyledon) of the rice grain embryo.
sc, seed coat.
o, oil droplets.
p, protein granules.

FIG. 3. Segment of a cross section of unpolished grain (Macan variety).
sc, seed coat.
al, aleurone layer of cells.
o, oil droplets.
p, protein granules.
sg, starch grains.

PLATE 8

FIG. 1. Cross section of unpolished rice grain (Macan variety).
sc, seed coat.
al, aleurone layer of cells.
en, endosperm with starch cells.
2. Cross section of polished rice grain (Macan variety).
al, part of aleurone layer of cells remaining after polishing.
en, endosperm with starch cells.
3. Fragment of rice hull showing surface hairs.

PLATE 9

FIG. 1. Pigeon ill with polyneuritis.
2. Same pigeon cured after taking rice bran.
3. Albino rat ill due to vitamin A deficiency.
4. Same albino rat cured completely after taking rice-bran oil for two weeks.

PLATE 10

Rice-bran cooker for heating rice bran to prevent deterioration.

TEXT FIGURE

FIG. 1. Outline showing Philippine process of milling rice.

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PLATE 1.

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PLATE 2.

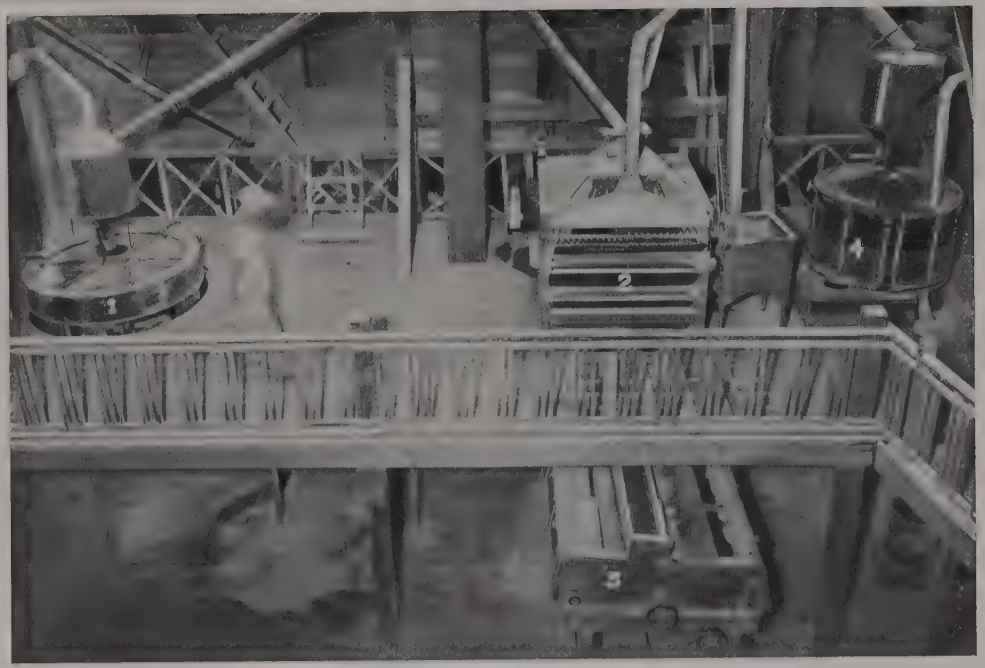
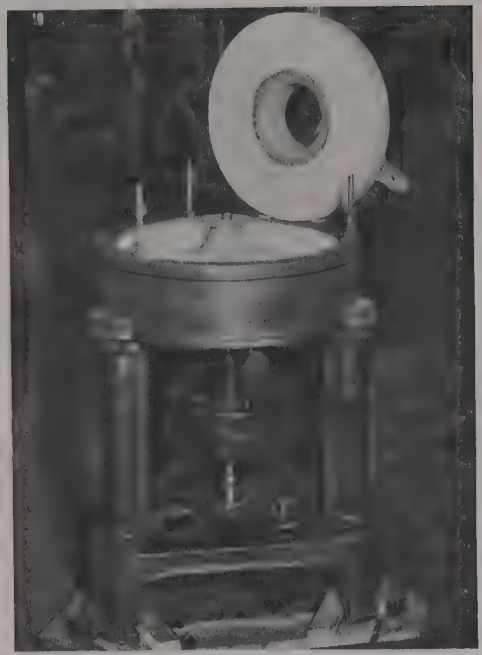


PLATE 3.



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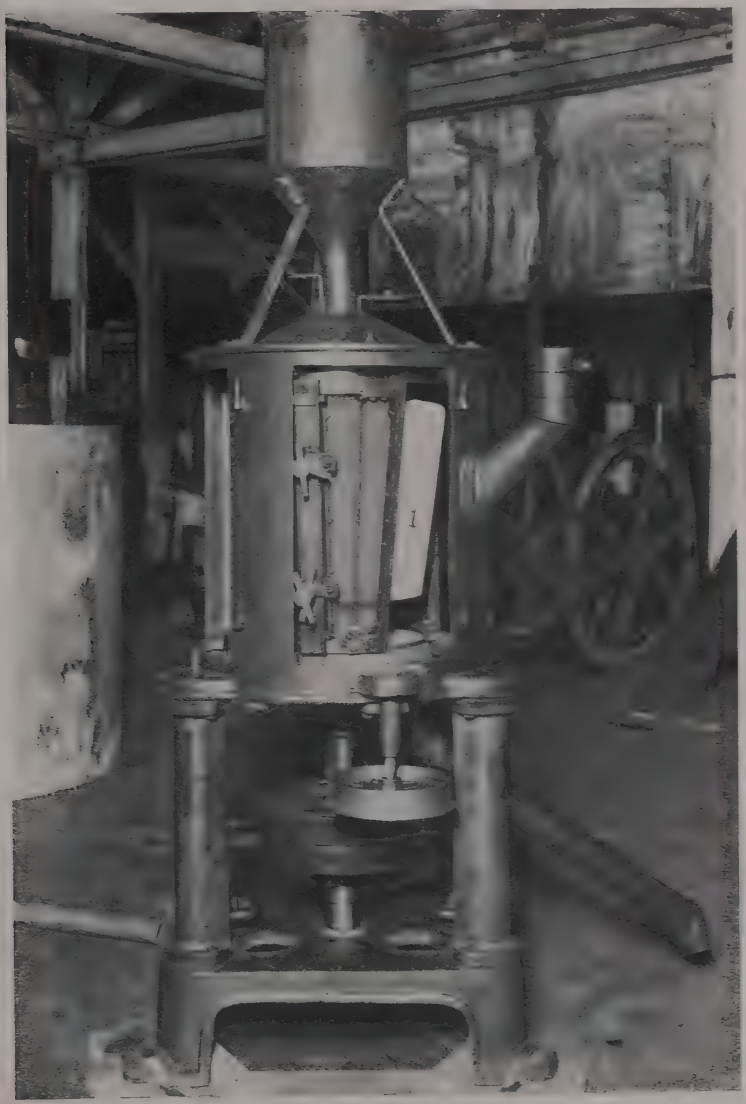
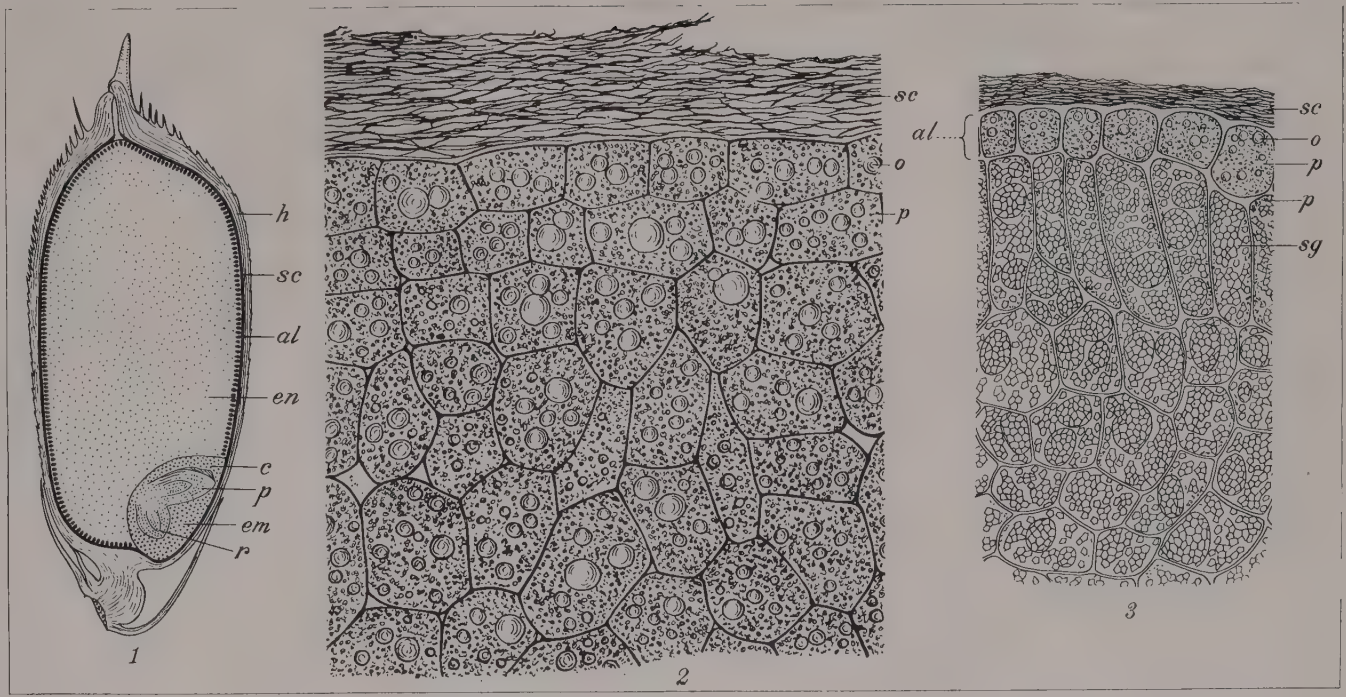


PLATE 5.

PLATE 6.



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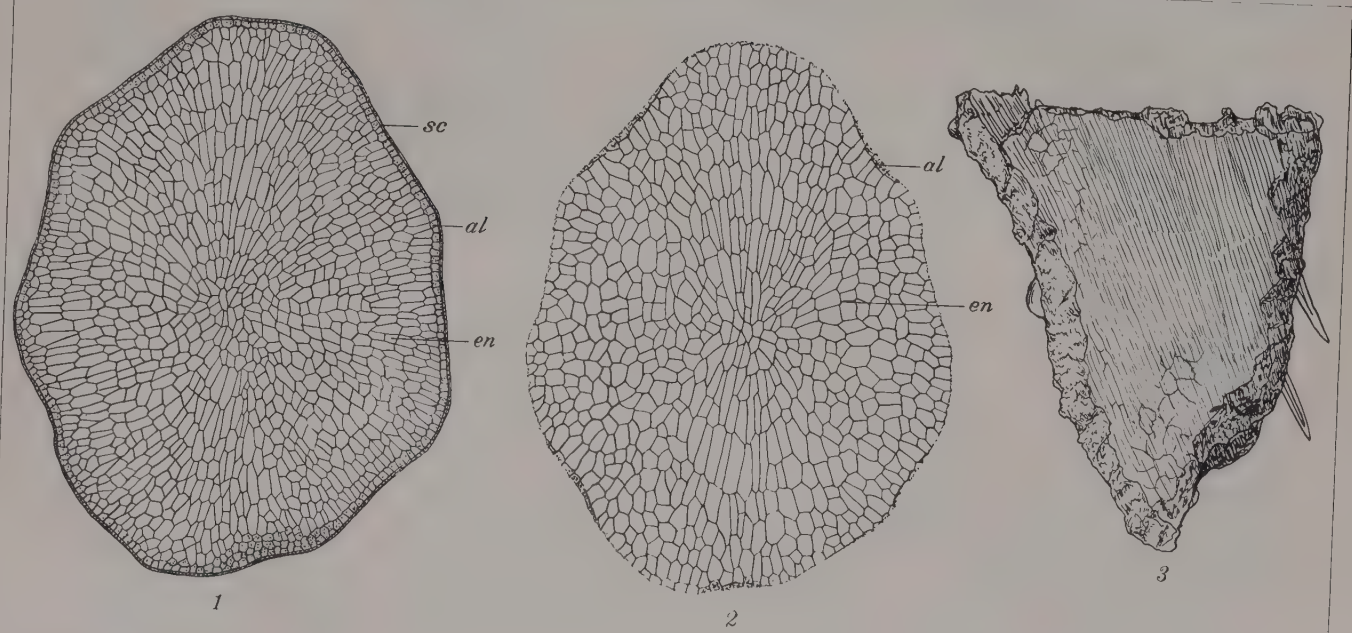

PLATE 8.

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PLATE 9.

PLATE 10.